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Environmental Regulation and Regional Economic Growth: An Input-Output Analysis of the Ohio Coal Mining Region

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INTRODUCTION

Coal producing counties in Ohio represent a chronically depressed region with a low rate of growth. Concern for the economic development and growth of such a depressed region demands a great deal of information on the structural interdependence of the regional economy. The input-output (I-O) analytical system serves as an extensive response to this need (40).

The major focus of this paper is to present and discuss the results of an I-O analysis for the region of major coal producing counties in Ohio. The model specification is presented in Appendices A and B. The model is an open, single-region, static, non-survey I-O model. This regional I-O model consists of 25 endogenous processing sectors, 2 exogenous final demand sectors, and 2 exogenous primary input sectors. The analysis focuses on the coal mining sector and related environmental regulations such as sulfur emission control and reclamation requirements.

The region studied is composed of 15 major coal producing counties in Ohio: Belmont, Carroll, Columbiana, Coshocton, Guernsey, Harrison, Holmes, Jefferson, Monroe, Morgan, Muskingum, Noble, Perry, Stark, and Tuscarawas. This study region comprises the eastern portion of the state of Ohio (Fig. 1). The region is typical of the central and northern Appalachian coalfield.

The 15-county study region represents the core of the coal mining industry of Ohio, where surface mining is the dominant method of extracting coal. As shown in Table 1, the study region produced 33 million tons of coal in 1978, accounting for about 82% of the Ohio total. Approximately 72% was surface mined, which accounts for more than 82% of surface mined coal in Ohio in 1978.

The two major economic characteristics of the study region are low income and high unemployment. During 1974-1979, the per capita income in the region was

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TABLE 1.—Ohio Coal Production by County and Methods of Mining (In 1,000 short tons).

		Underground			Surface		
County	Total	Mines Reporting	1,000 Short Tons	Percent of Total	Mines Reporting	1,000 Short Tons	Percent of Total
Ohio	40,094	31	11,389	28.4	440	28,705	71.6
Study Region	32,833	23	9,172	27.9	329	23,651	72.1
(Percent of Ohio Total)	(81.9)	(74.2)	(80.5)		(74.8)	(82 4)	
Belmont	9,235	6	3,891	42.1	90	5,344	57.9
Carroll	280				16	280	100.0
Columbiana	1,027	3	23	2.2	29	1,004	97.8
Coshocton	1,654	1	199	12.0	21	1,455	88.0
Guernsey	707				14	707	100.0
Harrison	5,137	8	2,282	44.4	23	2,855	55.6
Holmes	710				7	710	100.0
Jefferson	2,656	1	2	0.1	39	2,654	99.9
Monroe	1,253	2	1,253	100.0			
Morgan	191				1	191	100 0
Muskingum	4,740				23	4,740	100.0
Noble	129				5	129	100 0
Perry	2,303	1	1,522	66.1	10	781	33 9
Stark	705				15	705	100 0
Tuscarawas	2,106	1			36	2,106	100.0
Rest of Ohio	7,261	8	2,217	30.5	111	5,054	69.5

Source: ODIR (36).

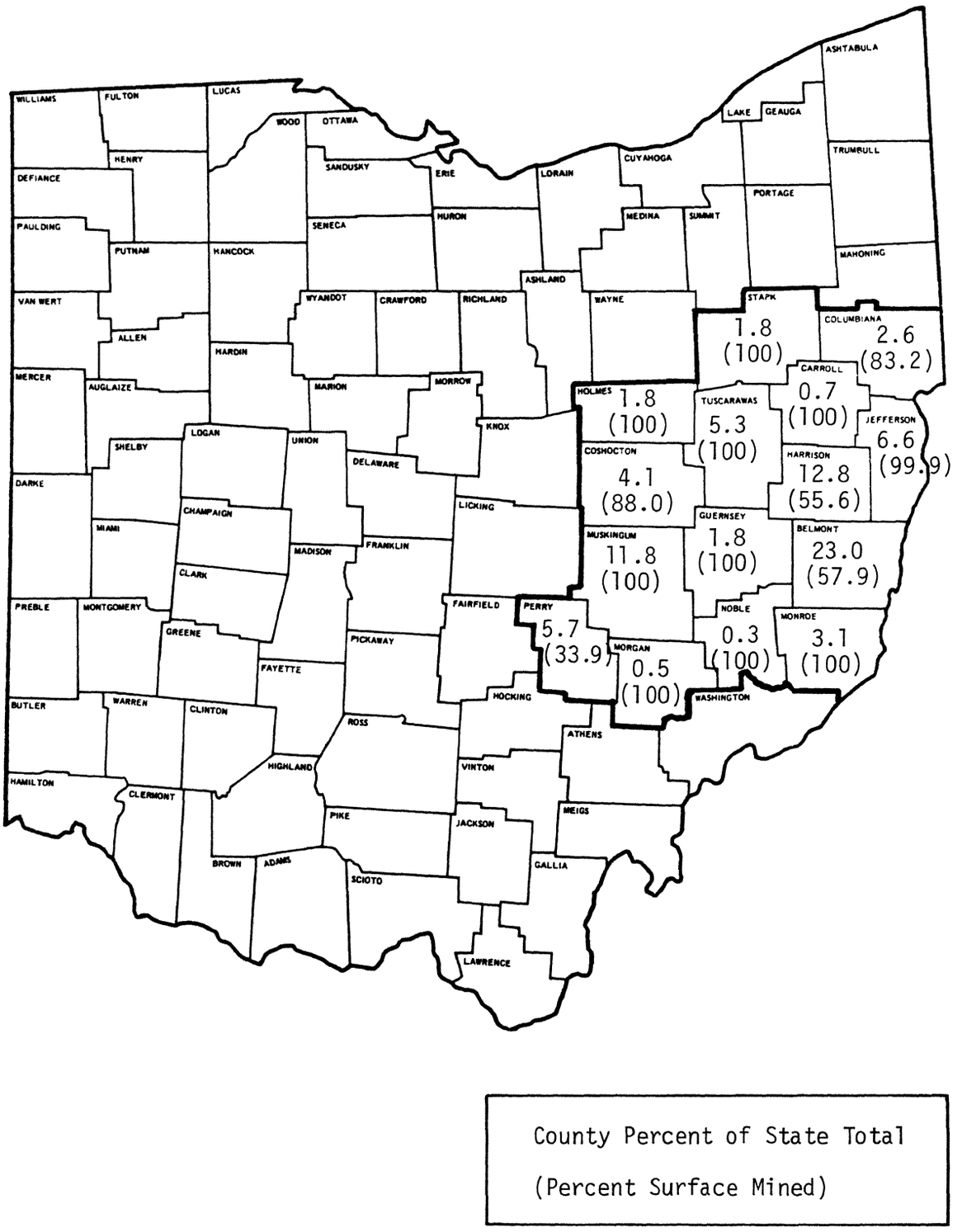

FIG. 1.—The 15-county study region.

about 20% less than per capita income in the state (60, 61). The average unemployment rate for the region in May 1983 was 16.6%, compared to 12.9% for the state (33).

The production and use of coal creates social costs such as costs of sulfur emission, degraded quality of water and aesthetics, and disrupted land use (2, 4). Recent federal and state environmental legislation mandates the reduction of these social costs, and the resulting environmental regulations affect the production (supply) of and use (demand) for coal. Two environmental regulations affecting the supply of and demand for coal mined in the 15-county region are the Clean Air Act of 1972 (42 U. S. C. 7425a) and the Surface Mine Control and Reclamation Act of 1977 (PL 95-87).

Coal is an important natural resource in the region. The region's economy is vulnerable to changes in the coal mining industry. Alternative development strategies based on industries other than coal mining are needed for this region in order to deal with regional growth and development in the event of a stagnating coal economy. Similarly, development strategies are needed in the event of coal industry growth due to expanding demand for coal. A regional I-O analytical system facilitates the evaluation of various alternative development strategies. Estimation of economic impacts of sulfur and reclamation regulations is an important part of this evaluation.

The general objective of this research is to evaluate alternative development strategies for the 15-county study region. First, the role of the coal mining industry in the region's economy is examined by identifying the interrelations among the coal mining sectors and other economic sectors. Then the impacts of sulfur and reclamation regulations on the regional economy are estimated from estimates of hypothetical changes in coal production due to these environmental regulations.[2]

As a conceptual background of the methodology used, the second section presents an overview of the I-O analytical system and its empirical implementation. In the third section, the primary results of the research are presented with their economic interpretations. The results are then used to examine the regional impacts of the coal industry. Finally, the summary of findings, conclusions, and policy implications are presented in the last section.

THE INPUT-OUTPUT MODEL

I-O analysis is a method of arranging economic information at the sectoral level on the basis of the linkage between the microeconomics of the firm and the macroeconomics of the economy. All I-O models consist of three parts: an interindustry flow table, a technical coefficients matrix, and an interdependence coefficients matrix.[3] The flow table is the base of an I-O model, from which the technical and interdependence coefficients are derived. Three assumptions underlying the model are fixed coefficient production functions, constant relative prices of inputs and outputs, and production of homogenous output in each sector (39). A mathematical specification of the I-O model is in Appendix A.

The flow table describes the demand and supply relationships of an economy in equilibrium by showing final demand for goods and services and the interindustry transactions required to satisfy this demand. In the flow table, the entire economy under consideration is divided into sectors comprised of processing sectors, final demand sectors, and primary input sectors. The processing sectors as either producing or purchasing sectors are endogenous, and the final demand and primary input sectors are exogenous.

Each sector consists of a set of relatively homogenous industries aggregated according to a predetermined classification. Each of these sectors produces a certain amount of output. This output may be used within the sector, sold to the other sectors as inputs, or flow to final demand sectors. According to Tiebout (55), industries are defined as aggregates of firms providing similar products while sectors refer to the kinds of market which industries serve. In this study, like in many other empirical studies, "sector" and "industry" are used interchangeably, however.

Impact Coefficients (Multipliers)

Since the input-output model was first pioneered by Leontief (24), a number of methodological improvements have been made. The concept of impact coefficients is one of the important outcomes of these improvements.[4] Impact coefficients or multipliers are quantitative measures of the effect that a change in the final demand for goods and services of a particular sector has on output, employment, and income of the whole economy. The output multiplier measures the amount of output generated by a $1 change in final demand for the output of a particular sector. The employment multiplier is the ratio of the total employment effect (direct plus indirect effect) to the direct employment effect in response to a change in final demand for a particular sector. The income multiplier is the ratio of the total income effect (direct plus indirect) to the direct income effect for a particular sector in response to a change in final demand.

Analytical Merit of I-O System

Despite a number of analytical deficiencies and the high costs of data gathering and processing, I-O models have been useful for practical general equilibrium analysis, specifically for measuring and analyzing interindustry flows and for determining the impact of

[2]Several empirical studies estimated likely changes in Ohio's coal production due to sulfur emission control and reclamation requirements For more details, see Schweers and Lillie (47) and Schlottman (46)

[3]The terminology in the I-O analysis is not entirely consistent among authors. Jones and Stipe (17) provide a comprehensive list of I-O definitions and synonyms

[4]Moore and Peterson (28) developed the concept of income and employment multipliers. The concept of income multiplier was developed further by Hirsch (15) The analysis of these multipliers or impact coefficients has since been a major part of the I-O analysis.

changes on the structure of a particular economy. The unique advantage of the I-O analytical system is that it facilitates impact analysis at the sectoral level by providing quantitative measures of the interindustry linkages and various kinds of sectoral impact coefficients (multipliers). This disaggregation advantage of the I-O model enables examination of the impact of a particular sector of interest on the rest of the economy. Since a major concern of the present study is the impact of changes in the coal mining sector on the regional economy, I-O analysis as a disaggregated analytical system appears to be preferable to other commonly used techniques such as economic base or econometric models.[5]

Another preferable feature of I-O analysis over other techniques, as far as the present research is concerned, is that its empirical implementation is relatively more free from data restrictions. Economic and social data at the regional level are generally very poor in detail and statistical reliability and rarely are published (29, 37). Regional economic base and econometric models strictly require an extensive set of regional data, while regional I-O analysis can be implemented using only regional sectoral employment data and the national I-O model. The adaptation of the national I-O model is also consistent with reducing the high cost of data gathering and processing in the estimation of the regional I-O model.

The most fundamental assumption behind I-O models is a set of constant fixed coefficient production functions. This assumption makes I-O models simpler but somewhat unrealistic in the sense that the linearity assumption in reality is violated by changes in product prices, input substitutions, and technological changes. A linear production function is a first approximation of a nonlinear production function and the question of whether or not the errors caused by first approximation are small enough to be ignored is a matter of empirical resolution. Chenery and Clark (8) concluded on the basis of their empirical work that the assumption of linear production function is not unreasonable in the real world [see also Miernyk (26) and Richardson (39)].

The rate of technological chage is slow enough for the I-O coefficients of 1 year to be assumed to hold in the years before and after (25, 63). Thus, even an out-of-date table of I-O coefficients will show something of value, *i.e.*, the maximum input requirement (39). While this study assumes that linear functions are valid, the computer/high technology revolution in production will reduce the stability of these functions in many industries.

A concluding remark is made on the distinction between "closed" and "open" I-O models. If all economic sectors in an I-O system are considered as being both producers and consumers, the system is represented by a closed model. In such a model, households constitute an economic sector whose output is labor and whose inputs are consumption goods and services. It has been demonstrated that closed models have great analytical merit (12, 64),[6] but they do not lend themselves readily to algebraic manipulation since they are completely circular with no exogenous variables (31, 64).[7] In the I-O system represented by open models, final demand is assumed to be related to other sectors but is autonomously determined by factors outside the system. Labor is considered as an input but not a functionally related product of households. The object of economic activities is satisfaction of final demand. One or more sectors' final demands can be changed, and the economic impacts of those changes can be estimated.

Empirical Generation of the Regional I-O Model

The regional I-O model of 15 major coal producing counties is derived from the 1978 U. S. national I-O model updated from the 1972 model. The step-by-step procedures for adaptation of the 1978 U. S. model to the study region are presented in Appendix B.

Subdivision of Coal Mining Sector

The present study emphasizes the coal mining sector and related environmental regulations such as sulfur emission control and surface mine reclamation requirements. The coal mining sector is divided into two subsectors in the regional I-O model: underground and surface coal mining sectors. This requires information on input purchases by the underground and surface coal mining sectors from other industries. An empirical study of the reclamation costs of Ohio surface mined land pointed out that the majority of coal mining companies in Ohio do not have detailed records on their input purchases (11). In order to check whether reliable information on input purchases at the sectoral level could be collected, a mail questionnaire survey along with a telephone interview was conducted.[8] None of the sample companies was found to be able to provide information on the sectoral breakdown of their input purchases. As an alternative, technical information from an I-O study done for the state of West Virginia is adapted (27).

The area of coal producing counties in Ohio is adjacent to and is similar in coal-oriented socio-economic conditions to the state of West Virginia. Both areas are rich in coal resources. Low per capita income and high unemployment are the two common economic problems in both areas (30, 44). High sulfur content is the common quality problem of coal produced in Ohio and West Virginia (23, 46). It is reasonable to assume that

[5]For more discussion on the limitations of the economic base model, see Prescott and Lewis (38), Richardson (40), and Shaffer (49). More details on the concept as well as the limitations of the econometric model are provided in Theil, *et al.* (54), Glickman (13), and Richardson (40).

[6]The closed I-O system takes into account the demand and supply factors simultaneously. By doing so, the system facilitates incorporation of induced effects of final consumption.

[7]Since the completely closed I-O system is homogenous, in algebraic terms, it has either a trivial solution or infinitely many proportionate solutions. For the complete mathematical presentation of the completely closed I-O system, see Yan (64).

[8]The questionnaire used in this test survey was developed on the basis of the questionnaire used in the West Virginia I-O study. See Appendix D in Ro (42).

the economies of those two areas have similar interindustry linkages between coal mining and other industries.

In their empirical study, Miernyk, *et al.* (27) constructed an I-O model consisting of 48 endogenous and 6 exogenous sectors of the West Virginia economy in 1965.[9] This model includes underground and surface coal mining industries as individual endogenous sectors. The technical coefficients from the West Virginia study are used to divide the national coal mining sector coefficients into underground and surface coal mining sector coefficients in this study. For details of this derivation, see Appendix B.

Accomplishment of Objectives

The regional technical coefficients were derived for the 24 endogenous sectors from the national technical coefficients. By subdividing the coal mining sector into underground and surface coal mining sectors, there are 25 endogenous sectors. The regional technical coefficients are then used to derive the regional transactions and the regional interdependence coefficients.

From the regional interdependence coefficients, the sectoral multipliers with respect to output, employment, and income are computed for each endogenous sector. Appendix A describes the computation of these multipliers. Then sectors are ranked according to the magnitude of these multipliers.

High unemployment and low per capita income are the two major economic problems in the study region. In the present study, sectors with high employment and income multipliers are identified as the high impact potential sectors in the sense that any positive (negative) changes in these sectors will have relatively large positive (negative) influences on employment or income throughout the regional economy.

The role of the coal mining industry is examined by looking at the interindustry linkages of the underground and surface coal mining sectors with other endogenous sectors, especially the high impact potential sectors. The column and row elements of the interdependence coefficients matrix for the coal mining sectors provide details on interindustry linkages between the coal mining sectors and other endogenous sectors.

The final objective is to determine the impact of sulfur and reclamation regulations on the regional economy. Schweers and Lillie (47) predicted that the demand for Ohio coal would decline by 3.1 million short tons per year due to the sulfur emission controls enforced by the Clean Air Act. This accounts for about 7.5% of total Ohio coal production in 1978. The effect of this estimated change on individual sectors of the regional economy is analyzed to examine the potential impact of sulfur emission controls.

[9]The interindustry flow data used in this model were obtained by means of a sample, interview survey. On the average, 3.3% of all establishments in each sector were used as the sample. Miernyk, *et al.* (27) showed through statistical tests that the sample establishments were a representative cross section of establishments in most sectors, and reported high response rates with complete cooperation in most sample establishments. They went on to conclude that the West Virginia I-O model was highly reliable.

Empirical studies show that reclaiming surface mined land in Ohio is clearly an incremental cost to surface coal mining without reclamation (11, 43). One consequence of this incremental cost, other things being equal, is a reduction in coal production. Schlottmann (46) estimated a reduction of 5.6% in 1978 coal production for northern Appalachia.[10] Since Ohio coal producing counties are included in northern Appalachia, the reduction rate of 5.6% is assumed applicable to the present study. The impact of the final demand portion of this reduction on individual sectors of the regional economy is analyzed to examine the potential impact of surface mine reclamation.

RESULTS OF THE REGIONAL INPUT—OUTPUT ANALYSIS

In this section the primary results of the regional I-O analysis for the 15 coal producing counties in eastern Ohio are presented. The flow table, the technical coefficients matrix, and the interdependence coefficients matrix are presented in Appendix C. An overview of the regional economy through the regional flow table (Appendix Table C-I) is presented first. Then the results based on the regional technical (Appendix Table C-II) and interdependence coefficients matrices (Appendix Table C-III) are presented with economic meanings and interpretations.

An Overview of the Regional Economy

With the sectoral income and employment figures, the regional flow table provides insights into the size and structure of the region's economy. The flow table shows regional outputs, imports, and exports at the sectoral level. It also shows sales and purchase distributions of individual endogenous sectors of the regional economy.

Output, Employment, and Income

The sectoral output, employment, and income figures for the region are presented in Table 2. Except for the agricultural sector and for the underground and surface coal mining sectors, the regional outputs for all sectors were computed (Appendix B). The output for the agricultural sector was obtained from Ohio Farm Income (32) and the output for the coal mining sectors from Ohio Division of Mines Report (36).

The employment for the agricultural sector was estimated as the sectoral output divided by the national output-employment ratio. The employment figures for the coal mining sectors were obtained directly from Ohio Division of Mines Report (36). The employment figures for the remaining sectors were obtained from Ohio County Business Patterns data on tape (59). The regional income for all sectors was estimated as the sectoral employment multiplied by the sectoral average annual earnings in the region.

The region is dependent on few sectors in terms of output, employment, and income (Table 2). The top

[10]Northern Appalachia includes eastern Pennsylvania, western Pennsylvania, northern West Virginia, and Ohio.

TABLE 2.—Sectoral Output, Employment, and Income for the Region, 1978.

Sectors	Output* (Million Dollars)	Employment† (Man-years)	Income‡ (Million Dollars)
Agriculture	347.7 **	8,634 ††	70.2
Underground Coal Mining	206.5 ‡‡	7,089 ‡‡	137.3
Surface Coal Mining	490.9 ‡‡	5,545 ‡‡	113.1
(Underground and Surface)	(697.4)‡‡	(12,634)‡‡	(251.0)
All Other Mining	290.7	2,627	37.2
Construction	94.6	9,973	170.6
Food and Kindred Products	823.9	5,890	76.9
Textile and Apparel	94.1	2,111	21.0
Lumber and Wood Products	370.1	6,866	89.6
Printing and Publishing	130.5	4,534	61.3
Chemicals and Plastics	1,061.1	10,592	162.6
Stone, Clay, and Glass	364.9	10,995	158.5
Primary Metals	3,010.6	30,987	577.4
Fabricated Metals	748.6	12,328	182.1
Mechanical Machinery	866.7	17,477	268.5
Electrical Machinery	444.3	8,839	119.4
Instruments and Equipment	295.8	4,225	62.2
Transportation and Warehousing	317.5	6,719	108.2
Communications	120.3	3,352	54.3
Utilities	862.2	5,366	91.5
Wholesale Trade	441.4	13,062	181.6
Retail Trade	526.8	40,214	342.8
Finance, Insurance, and Real Estate	802.1	11,543	125.6
Services	2,770.4	58,385	81.1
Federal Government	22.3	3,210	58.5
State and Local Government	99.6	40,025 ***	447.3
Total	16,423.6	330,588	4,299.3

Sources: *Computed by Appendix equation B3.
†USDC (59).
‡Computed by Appendix equation B4. For average annual earnings, see Appendix Table B-II.
**OARDC (32).
††USDC (57) and OARDC (32).
‡‡ODIR (36).
***OBES (33).

five output producing sectors in the region are primary metals, services, chemicals and plastics, mechanical machinery, and utilities. In 1978 these five sectors generated an output of $8.6 billion, accounting for more than one-half of the total regional output of $16.4 billion. The top five sectors in employment are the services, retail trade, state and local government, primary metals, and mechanical machinery sectors, accounting for more than one-half of the 1978 total regional employment of 331,000 man-years. These sectors are also included in the group of the top ten sectors in terms of income, and account for more than two-fifths of the total regional income of $4.3 billion generated in 1978.

Exports, Imports, and Inputs

The region appears to be a net exporter. In 1978 the region exported $4.0 billion of goods and services, while it imported $1.1 billion of goods and services from outside the region (Table 3). The region's net exports of $2.9 billion account for 17.7% of the region's 1978 total production of $16.4 billion (Table 2). The remaining 82.3% was sold to meet the region's total intermediate demand (40.9% or $6.7 billion) and total consumption demand (41.5% or $6.8 billion).

Twelve out of 25 sectors were net exporters in 1978. The volume of exports for individual sectors was computed as the difference between estimates of sectoral total output and sectoral total demand. Exports are most important to the stone, clay, and glass sector. Approximately 72% of the stone, clay, and glass sector's outputs were sold outside the region in 1978 (Table 4). Other sectors which sell more than one-half of their outputs outside the region are coal mining (61.5%), primary metals (57.6%), and fabricated metals (51.3%).

Like the amount exported, the amount imported is also a net figure. The excess of demands above that produced within the study region was considered to be imported. Any increase in the final demand for the output of those sectors importing from outside the region would further increase the volume of imports unless the production capacities of those importing sectors are further increased within the region. For this reason, importing sectors are often considered as bottleneck sectors in the sense that their present production capacities are not capable of meeting the existing demand. In Table 3, 13 importing or bottleneck sectors are identified for the region. A notable one is the textile and apparel sector. In 1978 the textile and apparel sector

TABLE 3.—Sectoral Intermediate Demand, Consumption Demand, Exports, and Imports for the Region, In $ Million, 1978.*

Sectors	Intermediate Demand	Final Demand		Net Imports
		Consumption	Net Exports	
Agriculture	301.7	63.2		17.2
Underground Coal Mining	131.4	9.0	66 1	
Surface Coal Mining	116.2	12.0	362.7	
(Underground and Surface)	(247.7)	(20.9)	(428.8)	
All Other Mining	249.9	3.7	37.1	
Construction	231.9	457.8		95.1
Food and Kindred Products	292.5	590.3		58.9
Textile and Apparel	16.7	163.1		85.7
Lumber and Wood Products	270.8	95.1	4.1	
Printing and Publishing	65.8	66.5		1.8
Chemicals and Plastics	731.2	366.5		36.6
Stone, Clay, and Glass	81.8	18.9	264.1	
Primary Metals	1,219.4	56.3	1,735.0	
Fabricated Metals	292.7	71.5	384.4	
Mechanical Machinery	322.2	431.8	102.7	
Electrical Machinery	107.4	207.6	129.3	
Instruments and Equipment	86.9	264.3		55.4
Transportation and Warehousing	98.3	153.4		34.2
Communications	57.8	83.8		21.3
Utilities	479.9	219.7	162.6	
Wholesale Trade	252.6	332.0		143.1
Retail Trade	26.6	669.0		168.0
Finance, Insurance, and Real Estate	312.4	883.2		393.5
Services	836.8	1,280.9	652.7	
Federal Government	38.5	19.3		5.5
State and Local Government	6.6	297.6	95.4	
Regional Total	6,728.6	6,816.5	3,996.2	1,116.8
(Percent of Total Production)	(40.9)	(41.5)	(24.4)	(−6.7)

*This table contains some rounding errors. So the sum of each row may not be identical to the corresponding sectoral total output presented in Table 2. In this summation, the import figures should be subtracted.

TABLE 4.—Sectoral Exports and Imports as Percentages of Sectoral Outputs and Regional Total Exports and Imports, 1978.

Sectors	Exports		Imports	
	Percent of Sectoral Outputs	Percent of Regional Total Exports*	Percent of Sectoral Outputs	Percent of Regional Total Imports*
Agriculture			4.9	1.6
Underground Coal Mining	32 0	3.2		
Surface Coal Mining	73 9	7.6		
(Underground and Surface)	(61.5)	(10 7)		
All Other Mining	13 0	0 9		
Construction			16.0	8.5
Food and Kindred Products			7.1	5.3
Textile and Apparel			91.1	7.7
Lumber and Wood Products	1 1	0.1		
Printing and Publishing			1.4	1.6
Chemicals and Plastics			3.5	3.3
Stone, Clay, and Glass	72.4	6.6		
Primary Metals	57.6	43.4		
Fabricated Metals	51.3	9.6		
Mechanical Machinery	12.0	2.6		
Electrical Machinery	29.1	3.2		
Instruments and Equipment			18.7	5.0
Transportation and Warehousing			10.8	3.1
Communications			17.7	1.9
Utilities	18.9	4.1		
Wholesale Trade			32.4	12.8
Retail Trade			31.9	15.1
Finance, Insurance, and Real Estate			41.9	35.2
Services	23.6	16.3		
Federal Government			10.5	0.5
State and Local Government	23.9	2.4		

*The column sum may not be equal to 100.0 due to the rounding error.

imported about $85.7 million of goods and services from outside the region, accounting for more than 91% of its output. Implied is that the region does not have comparative advantage in textiles. The finance, wholesale trade, and retail trade sectors are ranked high in the percentage of imports to their outputs (Table 4).

Each endogenous sector purchases inputs from intermediate and primary input sectors. The percentage of inputs purchased from intermediate input sectors for each sector ranges from a high of 55.7% for the food sector to a low of 18.1% for the retail and federal government sectors (Table 5). An average sector of the regional economy purchases about two-fifths of its total inputs from other intermediate input sectors.

Primary inputs consist of value added (labor and capital) and imports. The retail trade sector purchases the highest percentage of its total inputs from the value added sector at 77.7%, while the food sector purchases the lowest at 25.6% (Table 5). An average sector purchases slightly more than one-half of its total inputs from the value added sector.

The third column of Table 5 shows input purchases from the import sector as the percentage of total input purchases. The underground coal mining sector purchases the lowest percentage of its total inputs from the import sector at 2.9%. Imported inputs account for more than one-half of total inputs in the case of the textile and apparel sector. An individual sector, on the average, purchases about one-tenth of its total input from outside the region.

Output, Employment, and Income Multipliers

The output, employment, and income multipliers were computed for each endogenous sector and are presented in Table 6. Shown in the first column are the output multipliers with their rankings. The output multiplier measures the amount of output directly and indirectly generated within the economy by a $1 change in final demand for the output of a particular sector. For example, the output multiplier for the instruments and equipment sector is the highest at 1.98. This means that a $1 change in final demand for the output of the instruments and equipment sector will cause a change in total output of $1.98 in the regional economy.

A larger multiplier indicates that there is a relatively greater interaction or interdependence between the associated sector and other sectors within the regional economy. These high output multiplier sectors are also ranked high in the percentage of intermediate inputs to total inputs, indicating greater interaction with other sectors (Table 5).

The relatively low output multipliers of the retail trade, federal government, wholesale trade, communications, and textile and apparel sectors signify small

TABLE 5.—Distribution of Total Input Purchases of the Regional Endogenous Sectors, 1978.*

Sectors	Inputs		
	Intermediate Inputs Percent	Value Added Percent	Imports Percent
Agriculture	39.4	47 9	13 6
Underground Coal Mining	27 6	69 5	2.9
Surface Coal Mining	25.9	70 3	3.8
(Underground and Surface)	(26.5)	(70 1)	(3.4)
All Other Mining	23.1	71 8	5.1
Construction	46 2	46.1	7 6
Food and Kindred Products	55.7	25 6	14 7
Textile and Apparel	22.3	27.5	50.2
Lumber and Wood Products	46.5	39 2	14 3
Printing and Publishing	36.7	58.5	4.8
Chemicals and Plastics	46.7	40 3	13.0
Stone, Clay, and Glass	34.2	59.6	6.2
Primary Metals	0.2	42.1	7.7
Fabricated Metals	52.3	42.5	5.2
Mechanical Machinery	47.0	47.7	5.2
Electrical Machinery	50.2	41.9	7.9
Instruments and Equipment	54.2	34.5	11.3
Transportation and Warehousing	33.3	58.0	8.6
Communications	19.2	74.6	6.2
Utilities	47.1	49.4	3.5
Wholesale Trade	19.4	77.2	3.5
Retail Trade	18.1	77.7	4.2
Finance, Insurance, and Real Estate	39.1	48.5	12.3
Services	29.7	59.9	10.3
Federal Government	18.1	73.0	8.9
State and Local Government	48.0	41.6	10.4
Average	37.3	53.0	9.7

*The sum of each row may not be equal to 100.0 due to the rounding error.

TABLE 6.—Output, Employment, and Income Multipliers for the Regional Endogenous Sectors, 1978.*

Sectors	Output Multiplier	Employment Multiplier	Income Multiplier
Agriculture	1.68 (12)	1.50 (14)	1.67 (11)
Underground Coal Mining	1.48 (18)	1.21 (20)	1.16 (23)
Surface Coal Mining	1.39 (19)	1.65 (13)	1.53 (14)
All Other Mining	1.38 (20)	1.67 (11)	1.65 (12)
Construction	1.79 (10)	1.91 (6)	1.71 (10)
Food and Kindred Products	1.97 (2)	3.54 (1)	2.09 (1)
Textile and Apparel	1.34 (21)	1.29 (19)	1.36 (17)
Lumber and Wood Products	1.81 (8)	1.74 (9)	1.79 (8)
Printing and Publishing	1.61 (13)	1.36 (17)	1.35 (18)
Chemicals and Plastics	1.80 (9)	2.16 (4)	2.08 (4)
Stone, Clay, and Glass	1.56 (15)	1.30 (18)	1.30 (19)
Primary Metals	1.86 (5)	2.18 (3)	2.00 (5)
Fabricated Metals	1.94 (3)	1.81 (8)	1.85 (7)
Mechanical Machinery	1.84 (6)	1.66 (12)	1.64 (13)
Electrical Machinery	1.89 (4)	1.70 (10)	1.75 (9)
Instruments and Equipment	1.98 (1)	2.09 (5)	2.09 (3)
Transportation and Warehousing	1.53 (16)	1.48 (15)	1.40 (16)
Communications	1.30 (22)	1.21 (21)	1.17 (22)
Utilities	1.74 (11)	1.70 (2)	2.60 (2)
Wholesale Trade	1.30 (23)	1.20 (22)	1.18 (21)
Retail Trade	1.29 (25)	1.07 (25)	1.10 (24)
Finance, Insurance, and Real Estate	1.61 (14)	1.86 (7)	2.00 (6)
Services	1.50 (17)	1.41 (16)	1.52 (15)
Federal Government	1.29 (24)	1.09 (24)	1.06 (25)
State and Local Government	1.83 (7)	1.14 (23)	1.18 (20)
Whole Economy	1.63	1.68	1.65

*Figures in parentheses are the ranks of multipliers. The output, employment, and income multipliers for the coal mining sector (underground and surface together) were estimated to be 1.42, 1.38, and 1.34.

backward linkages of these sectors with other sectors. The primary dampening influences on the sectoral output multiplier are the payments made for imports of goods and services and other payments for the primary inputs other than imported inputs. This is evident from the fact that sectors with relatively low output multipliers are ranked high in the percentage of input purchases from either the value added sector or the import sector (Table 5).

The unweighted average of output multipliers for all sectors can be considered as an output multiplier for the economy as a whole if it is assumed that final demand changes by the same absolute amount in all sectors. Under this condition, a $25 change in regional final demand (a $1 change in each sector) would generate a change in output of $40.70 in the regional economy. Dividing this total by the amount of the change in final demand indicates that every $1 change in final demand generates, on the average, an output change of $1.63 in the regional economy.[11]

Presented in the second column are sectoral employment multipliers with their rankings. The employment multiplier in this study measures the total employment change in man-years generated in the regional economy as a result of a man-year of employment added to a particular sector. For instance, a 1-man-year change in employment in the food and kindred products sector would generate the highest employment of 3.54 man-years in the regional economy. Likewise, a 1-man-year change in employment in the retail trade sector is estimated to create only 1.07 man-years of employment. The employment multiplier is relatively large in the capital intensive sectors. In addition to food and kindred products, such sectors as utilities, primary metals, chemicals and plastics, and instruments and equipment have employment multipliers greater than 2.00. The employment multiplier for the regional economy as a whole was estimated to be 1.68.

Sectoral income multipliers are shown in the third column of Table 6 with their rankings. The interpretation of the income multiplier is analogous to that for the employment multiplier. The income multiplier is the largest in the food and kindred products sector at 3.09, indicating that a $1 increase in that sector's income will generate the highest additional income of $3.09 in the regional economy. In addition to food and kindred products, such sectors as utilities, instruments and equipment, chemicals and plastics, primary metals, and finance, insurance, and real estate have relatively large income multipliers. An increase in income in any one of these sectors would have a relatively large effect on the income throughout the regional economy. The income multiplier for the regional economy as a whole was estimated to be 1.65.

Since the major economic problems of the region are high unemployment and low per capita income, sectors with high employment and income multipliers are identified as the high impact potential sectors in the regional economy. The top ten sectors ranked by the employment multiplier and by the income multiplier

[11]This unweighted average multiplier excludes any consideration of the size of each sector and may be much different than an average multiplier based on a constant percent increase in output in each sector.

TABLE 7.—Sectors Most Closely Related to the High Employment and Income Multiplier Sectors In Terms of Selling Outputs and Purchasing Inputs.

High Multiplier Sectors	Top Three Related Sectors		
	1	2	3
		Selling Outputs	
Construction	State and Local Government	Utilities	Communications
Food and Kindred Products	Agriculture	Services	Finance, Insurance, and Real Estate
Lumber and Wood Products	Printing and Publishing	Construction	Food and Kindred Products
Chemicals and Plastics	Electrical Machinery	Lumber and Wood Products	State and Local Government
Primary Metals	Fabricated Metals	Mechanical Machinery	Electrical Machinery
Fabricated Metals	Instruments and Equipment	Construction	Electrical Machinery
Electrical Machinery	Mechanical Machinery	Instruments and Equipment	Primary Metals
Instruments and Equipment	Services	Electrical Machinery	Transportation and Warehousing
Utilities	State and Local Government	Stone, Clay, and Glass	Primary Metals
Finance, Insurance, and Real Estate	Other Mining	Retail Trade	Services
		Purchasing Inputs	
Construction	Fabricated Metals	Primary Metals	Services
Food and Kindred Products	Agriculture	Chemicals and Plastics	Services
Lumber and Wood Products	Chemicals and Plastics	Primary Metals	Services
Chemicals and Plastics	Services	Primary Metals	Utilities
Primary Metals	Other Mining	Chemicals and Plastics	Utilities
Fabricated Metals	Primary Metals	Chemicals and Plastics	Services
Electrical Machinery	Primary Metals	Chemicals and Plastics	Services
Instruments and Equipment	Primary Metals	Fabricated Metals	Chemicals and Plastics
Utilities	Coal Mining	Chemicals and Plastics	Other Mining
Finance, Insurance, and Real Estate	Services	Utilities	Printing and Publishing

are the same with slightly different rankings (Table 6). Expansion of any one of these sectors is consistent with employment and income stimulating policies. Furthermore, it is also consistent with output expansion policies. Eight of these sectors are in the top ten sectors ranked by output multipliers.

Table 7 shows the top three sectors in terms of selling outputs and of buying inputs for each of the top ten sectors as ranked by employment or income multipliers. For example, the three largest buyers from the construction sector are the state and local government, utilities, and communications sectors, while the construction sector makes its largest input purchases from the fabricated metals, primary metals, and services sectors. Output sales are very dispersed, with 19 out of 24 sectors appearing in Table 7. The most frequently appearing sectors are electrical machinery, services, and state and local government. Input purchases are more concentrated, with only 9 of 24 sectors appearing in Table 7. Chemicals and plastics, primary metals, and services are the most frequently appearing sectors. The services sector emerges from Table 7 as an important sector in the region because it is an important input supplier to seven other sectors.

THE COAL MINING INDUSTRIES

In 1978 the coal mining sector (underground and surface together) generated $697.4 million of output, earned $251.0 million of income, and had 12,634 man-years of employment (Table 2). This sector was 9th in the region in output, 6th in income, and 7th in employment.

The coal mining sector is one of the region's largest exporters. In 1978 the sector sold $428.8 million of its output outside the region (Table 3). The coal mining sector was second in the region in the percentage of sectoral exports to sectoral outputs (61.5%) and third in the percentage of sectoral exports to total regional exports (10.7%). The coal mining sector appears to be highly dependent on primary inputs rather than intermediate inputs. The sector purchases more than two-thirds of its total inputs from the primary inputs sectors (Table 5), nearly all of which is value added (labor and capital), and sells more than three-fifths of total output to the final consumption and export demand sectors (Table 3).

The coal mining sectors are found within the group of the bottom ten sectors ranked by the output multiplier (Table 6). The output multiplier is slightly higher in the underground than in the surface coal mining sector. The coal mining sectors also have relatively low multipliers for employment and income. The underground coal mining sector is in the group of the bottom six sectors ranked by the employment and income multipliers. The surface coal mining sector is ranked 13th in terms of the employment multiplier and

TABLE 8.—Coal Mining Sectors' Direct and Indirect Input Purchases and Output Sales per $100 of Sectoral Output, 1978.

	Purchasing Inputs*		Selling Outputs†	
Sectors	Underground	Surface	Underground	Surface
Agriculture	0.13	0.13	0.16	0.11
Underground Coal Mining	101 30	6.63	101.30	1.71
Surface Coal Mining	1.71	111.90	6.63	111.90
All Other Mining	1.03	0.20	0.27	0.22
Construction	1.79	0.26	0.36	0.23
Food and Kindred Products	0.24	0.27	0.22	0.16
Textile and Apparel	0.05	0.03	0.12	0.08
Lumber and Wood Products	1.36	0.00	0.67	0.43
Printing and Publishing	0.13	0.12	0.21	0.14
Chemicals and Plastics	11.39	1.32	0.50	0.33
Stone, Clay, and Glass	1.20	0.11	0.76	0.54
Primary Metals	6.17	1.87	2.61	1.61
Fabricated Metals	1.38	1.48	1.02	0.64
Mechanical Machinery	6.83	4.37	0.69	0.44
Electrical Machinery	0.36	0.43	0.66	0.43
Instruments and Equipment	0.31	0.10	0.62	0.43
Transportation and Warehousing	0.79	0.61	0.12	0.08
Communications	0.16	0.14	0.14	0.10
Utilities	6.04	0.94	7.68	5.55
Wholesale Trade	2.13	1.39	0.12	0.08
Retail Trade	0.11	0.04	0.26	0.19
Finance, Insurance, and Real Estate	0.71	2.48	0.24	0.17
Services	2.65	3.95	0.25	0.18
Federal Government	0.10	0.10	0.22	0.16
State and Local Government	0.04	0.02	0.65	0.50

*Figures are the column elements of the regional interdependence coefficients matrix for the underground and surface coal mining sectors multiplied by 100.

†Figures are the row elements of the regional interdependence coefficients matrix for the underground and surface coal mining sectors multiplied by 100.

14th in terms of the income multiplier (Table 6).

The smaller employment multiplier in the underground than in the surface coal mining sector (1.21 compared to 1.65) is mainly because the underground coal mining sector is more labor intensive. The same is true with respect to income. The income multiplier is smaller in the underground coal mining sector than in the surface coal mining sector (1.16 compared to 1.53).

Table 8 shows how the coal mining sectors are related to other endogenous sectors within the region. In the first column are shown the input purchases per $100 of output by the underground coal mining sector directly and indirectly from all other sectors. It is the underground coal sector's column of the interdependence coefficients matrix (Appendix Table C-III) multiplied by 100. In order to produce $100 of output, the underground coal mining sector makes its largest input purchases from chemicals ($11.4), mechanical machinery ($6.8), primary metals ($6.2), utilities ($6.0), services ($2.7), and wholesale trade ($2.1).

Presented in the second column is the surface coal mining sector's column of the interdependence coefficients matrix (Appendix Table C-III) multiplied by 100. The surface coal mining sector appears to be highly dependent on itself in purchasing inputs. In order to produce $100 of output, this sector purchases the largest amount of direct and indirect inputs from itself at $11.9. The five sectors from which the surface coal mining sector makes its largest direct and indirect input purchases are underground coal mining ($6.6); mechanical machinery ($4.4); services ($4.0); finance, insurance, and real estate ($2.5); and primary metals ($1.9).

In the third column is presented the underground coal mining sector's row of the interdependence coefficients matrix (Appendix Table C-III) multiplied by 100. It shows how the underground coal mining sector's output is distributed among other endogenous sectors when it is assumed that final demand changes simultaneously by $100 in all sectors. For example, each $100 of final demand in the utilities sector results in an increase of about $7.70 in the underground coal mining sector's output. In addition to the utilities sector, other large sales impacts come from surface coal mining ($6.6), primary metals ($2.6), and fabricated metals ($1.0). Internal sales within the underground coal mining sector are also significant ($1.3).

The last column shows the direct and indirect increases in surface coal mining sales when it is assumed that all sectors simultaneously increase sales by $100. It is found by multiplying the surface coal mining sector's row of the interdependence coefficients matrix (Appendix Table C-III) by 100. The surface coal mining sector makes its largest output sales to itself ($11.9). As expected, the utilities sector is one of the largest buyers from the surface coal mining sector

TABLE 9.—Expected Decreases in Output, Employment, and Income of the Regional Endogenous Sectors Due to Sulfur Regulations, 1978.

Sectors	Output ($1,000)	Employment (Man-years)	Income ($1,000)
Agriculture	68.0	1.7	13.7
Underground Coal Mining	18,127.8	621.8	12,036.9
Surface Coal Mining	41,462.5	464.4	9,548.9
(Underground and Surface)	(59,590.3)	(1,086 2)	(21,585.7)
All Other Mining	234.1	2.1	30.0
Construction	372.8	6.2	107.0
Food and Kindred Products	137.4	1.0	12.8
Textile and Apparel	18.1	0.4	4.0
Lumber and Wood Products	319.5	5.9	77.4
Printing and Publishing	64.2	2.2	30.2
Chemicals and Plastics	2,249.2	22.3	344.1
Stone, Clay, and Glass	227.2	6.8	98.7
Primary Metals	1,642.7	16.8	314.9
Fabricated Metals	759.2	12.5	184.6
Mechanical Machinery	2,664.8	54.4	834.1
Electrical Machinery	212.7	4.0	57.0
Instruments and Equipment	84.2	1.2	17.7
Transportation and Warehousing	346.2	7.3	117.9
Communications	76.9	2.1	4.7
Utilities	1,281.8	7.7	15.9
Wholesale Trade	843.8	24.9	347.1
Retail Trade	34.6	2.6	22.5
Finance, Insurance, and Real Estate	1,023 6	14.3	660.3
Services	1,863.7	39.1	389.5
Federal Government	51.8	3.2	58.0
State and Local Government	13.9	1.4	15.6
Total*	74,180.2	1,326.3	24,993.4

*The sum of the elements in each column may not be equal to the column total due to the rounding error.

($5.6). Other sectors to which the surface coal mining sector makes relatively large output sales are underground coal mining ($1.7) and primary metals ($1.6).

In sum, the coal mining industries do not appear to be leading sectors of the regional economy. Their multipliers for output, employment, and income are relatively low. However, they seem to play significant roles in the regional economy as input purchasing sectors from utilities; primary metals; chemicals and plastics; fabricated metals; finance, insurance, and real estate; and services. The underground coal mining sector is more labor intensive than the surface coal mining sector. Consequently, the employment and income multipliers are higher in the surface than in the underground coal mining sector.

Impacts of Sulfur Emission Controls

Sulfur regulations affect both the underground and surface coal mining sectors. The Schweers and Lillie (47) estimate that the demand for Ohio coal would decline by 3.1 million tons or 7.5% of total Ohio coal produced in 1978 as a result of sulfur regulations is used to examine the potential impact on the region. This is equivalent to a $52.3 million reduction in the demand for coal produced in the study region.

Economic impacts of this reduction were estimated in two steps. First, on the basis of the output ratio between the two coal mining sectors, the reduction of $52.3 million was broken down into a $15.5 million reduction in the underground coal mining sector's final demand and a reduction of $38.8 million in the surface coal mining sector's final demand. Then impacts of these respective final demand changes on each endogenous sector's output, employment, and income were estimated (see Appendix equations B20, B21, and B22) and summed to represent total economic impacts of sulfur regulations. The results are presented in Table 9.

In the first column are shown the estimated decreases in each sector's output. The estimated decrease in output is the largest in the surface and underground coal mining sectors, followed by mechanical machinery, chemicals and plastics, services, primary metals, utilities, and finance, insurance, and real estate. The expected output decrease in the region as a whole was estimated to be $74.2 million, accounting for about 0.45% of total regional output. The surface and underground coal mining sectors together bear more than 80% of this total regional decrease.

The last two columns of Table 9 present the estimated decrease in each sector's employment and income due to the implementation of sulfur regulations. The expected decreases in both employment and income are relatively large in underground coal mining, surface coal mining, mechanical machinery, services, wholesale trade, chemicals and plastics, and primary metals. The underground and surface coal mining sectors together account for more than 80% of total regional employment and income decreases. The expected employment and income decreases in the region as a whole were estimated to be 1,326 man-years and $25.0 million, respectively. These figures account for about 0.40% of total regional employment and about 0.58% of total regional income, respectively.

As a result of the implementation of sulfur regulations, changes in output may also occur in sectors other than the coal mining sectors. For example, improved air quality resulting from the implementation of sulfur regulations may cause positive changes in some sectors. The use of scrubbers would increase output in sectors such as electrical machinery, while the need for enforcement of regulations would increase output in the government sectors. Estimation of these effects was beyond the scope of this study. Consequently, the above estimates probably overstate the size of the impacts.

Impacts of Reclamation Requirements

Unlike the case of sulfur regulations, the surface coal mining sector alone is affected by changes in the demand for coal due to reclamation regulations. The Schlottmann (46) estimate that surface coal production in Ohio would decline by 5.6% due to reclamation regulations imposed on surface coal mining is used to examine the potential impacts of reclamation on this region. This is equivalent to an output reduction of $27.5 million in the surface coal mining sector in the 1978 regional I-O model. This output reduction can be considered as a final demand reduction since it is an autonomous reduction to the surface coal mining sector's output. The expected effects of this final demand reduction on each endogenous sector's output, employment, and income (estimated by Appendix equations B20, B21, and B22) are presented in Table 10.

In the first column are shown the estimates of output decrease in each sector. The estimated decrease in output is largest in surface and underground coal mining, followed by mechanical machinery; services; finance, insurance, and real estate; primary metals; fabricated metals; wholesale trade; and chemicals and plastics. The underground and surface coal mining sectors together account for more than 80% of the total regional output decrease due to reclamation regulations. For the region as a whole, an output decrease of $38.4 million was estimated. This estimate accounts for about 0.24% of regional total output.

Presented in the last two columns are the estimated decreases in each sector's employment and income due to reclamation regulations. The largest decreases in both employment and income occur in the coal mining sectors. The underground and surface coal mining sectors together account for about 80% of the total regional decreases in employment and income. For the region as a whole, the expected decrease in employment and income was estimated to be about 515 man-years and $9.7 million, respectively. These respective figures account for about 0.16% of total regional employment and about 0.23% of total regional income. Other sectors with a relatively large decrease in their employment and income are the mechanical machinery, services, wholesale trade, and finance, insurance, and real estate sectors.

As in the impact analysis of sulfur regulations, possible changes in sectors other than the surface coal min-

TABLE 10.—Expected Decreases in Sectoral Output, Employment, and Income of the Regional Endogenous Sectors Due to Reclamation Regulations, 1978.

Sectors	Output ($1,000)	Employment (Man-years)	Income ($1,000)
Agriculture	36 1	0 9	7 3
Underground Coal Mining	1,827 6	62 7	1,214 5
Surface Coal Mining	30,866 6	348 6	7,108 6
(Underground and Surface)	(32,716 1)	(410 5)	(8,323 2)
All Other Mining	55 9	0 5	7 2
Construction	71 6	1 2	20 6
Food and Kindred Products	74 5	0 5	7 0
Textile and Apparel	8 3	0 2	1 9
Lumber and Wood Products	81 7	1 6	19 8
Printing and Publishing	32 9	1 2	15 5
Chemicals and Plastics	363 0	3 6	55 6
Stone, Clay, and Glass	30 8	1.0	13 5
Primary Metals	515.3	5 3	98 8
Fabricated Metals	408 5	6 7	99.4
Mechanical Machinery	1,204.1	24 6	377.8
Electrical Machinery	117 9	2 3	31 8
Instruments and Equipment	27.1	0.4	5 8
Transportation and Warehousing	168.0	3.6	57 2
Communications	38.8	1.1	17.5
Utilities	284 9	1.7	27.5
Wholesale Trade	384.7	11.3	158 2
Retail Trade	12.1	1.0	7 9
Finance, Insurance, and Real Estate	684.0	9.8	111 9
Services	1,088 4	22 9	228 3
Federal Government	27.6	1.8	30.8
State and Local Government	6.3	0.7	7.0
Total*	38,390.4	514.7	9,725.5

*The sum of the elements in each column may not be equal to the column total due to the rounding error.

ing sector were not considered in the impact analysis of reclamation regulations. For example, an output expansion may occur in the agriculture and underground coal mining sectors as a result of the implementation of reclamation regulations, but this was not considered in the impact analysis due to the lack of information. An output increase in the underground coal mining sector might result because the comparative advantage in underground coal production improves as reclamation requirements increase costs of surface coal production. The use of reclaimed land for agricultural purposes might result in an output increase in the agriculture sector. The inclusion of these output increases in the impact analysis may change the original results, especially with respect to the agriculture and underground coal mining sectors. For this reason, the above estimates for reclamation regulations overstate the size of the impacts.

In summary, the coal mining sectors bear a major portion of total regional impacts of the regulations. Negative economic impacts of the regulations are relatively large in sectors closely related to the coal mining sectors. However, the estimation of potential offsetting positive impacts in other sectors was beyond the scope of this study. The estimated economic impacts of sulfur and reclamation regulations on the regional economy as a whole are small and biased upward because of these omissions.

CONCLUSIONS and IMPLICATIONS

The main objective of this study was to develop an I-O model for the major coal producing region of Ohio, and through the model to estimate the structural interdependence of the region's economy. An open, single-region, static, non-survey I-O model was derived from the 1978 U. S. national I-O model updated from the 1972 model. In this model the coal mining industry was divided into the underground and surface coal mining sectors. Special attention was focused on the coal mining sector and related sulfur and reclamation regulations.

Conclusions

The research findings of this study lead to several important conclusions. First, the five largest sectors in terms of output generated within the study region are primary metals, services, chemicals and plastics, mechanical machinery, and utilities. These five sectors together account for more than one-half of regional output and 40% of employment and income. Coal accounts for 4.2% of output, 3.8% of employment, and 5.8% of income in the region.

Second, the study region is a net exporter. The region's largest net exporting sectors are coal mining (underground and surface together); stone, clay, and glass; primary metals; and fabricated metals. These sec-

tors each export more than one-half of their total output and together account for 70% of total exports from the region.

Third, the textile and apparel sector is not linked to the regional economy. It imports more than 90% of its total output. The other large importing sectors are finance, insurance, and real estate; wholesale trade; and retail trade. The finance, insurance, and real estate sector imports about one-half of its total output and the other two sectors import more than 30% of their outputs.

Fourth, the high impact potential sectors with respect to employment and income multipliers are construction, food and kindred products, lumber and wood products, chemicals and plastics, primary metals, fabricated metals, electrical machinery, instruments and equipment, utilities, and finance, insurance, and real estate. These multipliers were considered to be more important than the output multiplier because of high unemployment and low per capita incomes in the region.

Fifth, the services sector appears to be an important supporting sector of the high multiplier sectors.

Sixth, the coal mining sectors have relatively low impact potential. The coal mining sectors' output, employment, and income multipliers are relatively modest.

Seventh, compared to the surface coal mining sector, the underground coal mining sector has higher interaction with other sectors and is more labor intensive. Consequently, the multiplier effect for output is larger for underground mining, but the multiplier effects for employment and income are larger for surface mining.

Eighth, the underground and surface coal mining sectors bear more than 80% of economic impacts of sulfur regulations on regional output, employment, and income.

Ninth, the surface coal mining sector alone suffers most of the economic impacts of reclamation regulations. This sector accounts for more than two-thirds of all the decreases in total regional output, employment, and income due to reclamation regulations.

Tenth, in addition to the coal mining sectors, sulfur and reclamation regulations have their largest impacts on the chemicals and plastics; primary metals; mechanical machinery; utilities; finance, insurance, and real estate; services; fabricated metals; and wholesale trade sectors. These are the sectors most closely related to the coal mining sectors.

Finally, economic impacts of the regulations appear to be minor on the regional economy as a whole. The estimated total regional decreases in output, employment, or income due to sulfur or reclamation regulations are 0.2% to 0.6% of total regional output, employment, or income.[12]

[12]These conclusions are based on the assumption of an exogenous household sector in the model. If the household sector was made endogenous in the model, the estimated impacts of regulations would be larger. Even if they are twice as large as the estimated impacts in this model, the total impacts on output, income, and employment are still less than 1%.

Policy Implications

The two basic economic problems in the study region are high unemployment and low income. Since coal is an important resource in this region, economic impacts of environmental regulations imposed on the use and extraction of coal are commonly believed to represent an important variable in dealing with these economic problems. Several policy implications are drawn from the results of the regional I-O analysis.

Based on industry size and the employment and income multipliers, the primary metals, chemicals and plastics, and utilities sectors might be given more attention since change in any one of these sectors would have relatively large impacts on regional employment and income. These three sectors also have relatively large output multipliers. Also, they appear to be economically viable in the region. Expansion or creation of local firms within these sectors is therefore suggested for improving their regional economy.

Construction, food and kindred products, instruments and equipment, and finance, insurance, and real estate are importing sectors. Expansion of these sectors would not only have large employment and income multiplier impacts, but would also make the regional economy more self-sufficient in these sectors. Expansion of these sectors would also increase the diversification of the regional economy. Instruments and equipment output could supply output needed for compliance with sulfur regulations. The services sector has also emerged as a large and an important supporting sector to the regional economy.

A primary dampening influence on the demand for coal is high sulfur content. Therefore, expansion of the coal mining industries should be considered in conjunction with technological improvements in the use of high sulfur coal or joint combustion with low sulfur biomass (1, 14). Policy interests of this kind include coal washing, coal liquefaction, coal gasification, solid waste, crop residue, and wood waste. Gowen (14) found coal washing to be cost effective.

Another dampening influence on the coal industry is the incremental cost of surface coal production resulting from the imposition of reclamation requirements (11, 43). Reclamation requirements based on the comprehensive plan for the alternative post-uses of reclaimed land, rather than "original contour" requirements, might be a good policy consideration for lessening the costs of reclaiming surface mined land.

The imposition of sulfur and reclamation policies seems to justify the environmental concern of the public. Economic impacts of sulfur and reclamation regulations are minor on the regional economy as a whole. The macro implication is that the adverse impacts of the use and extraction of coal can be adequately controlled at a relatively low cost to the regional economy. However, economic impacts of sulfur and reclamation regulations are relatively large in the coal mining sectors. The relaxation or enforcement of the regulations therefore remains as an important policy variable in dealing with the region's basic economic problems.

REFERENCES

1. Abdallah, Mohammed H. 1978. Economics of Corn Stover as a Supplement in Steam-Electric Power Plants in the North Central United States. Unpublished Ph. D. Dissertation, The Ohio State Univ.
2. Board on Unreclaimed Strip Mined Land. 1974. *Land Reborn: A Study of Unreclaimed Coal Strip Mined Land in Ohio.* Ohio Dept. of Natural Resources, Columbus.
3. Boisvert, R. N. and N. L. Bills. 1976. A Non-Survey Technique for Regional I-O Models: Application to River Basin Planning. Cornell Univ., Dept. of Agri. Econ., A. E. Res. 76-19.
4. Brown, A. J. and E. M. Burrows. 1977 *Regional Economic Problems.* George Allen & Unwin, Ltd., London.
5. Brucker, S. M. and S. E. Hastings. An Evaluation of Non-Survey Estimation Techniques for Regional Input-Output Models. *Review of Regional Studies,* Vol. 13, No. 1.
6. Cartwright, J. V., R. M. Beemiller, and R. D. Gustely. 1981. Regional Input-Output Modeling System. U. S. Dept. of Commerce, Bureau of Economic Analysis, Washington, D. C.
7. Catlett, L. and M. Boehlje. 1979. Strip-Mine Reclamation Laws and Regional Cost Implications. *Southern J. Agri. Econ.,* Vol. 11, No. 1.
8. Chenery, H. B. and P. G. Clark. 1959. *Interindustry Economics.* John Wiley & Sons, New York, N. Y.
9. Czamanski, S. and E. E. Malizia. 1969. Applicability and Limitations in the Use of National Input-Output Tables for Regional Studies. *Papers, Reg. Sci. Assoc,* Vol. 23.
10. Doeksen, G. A. and D. F. Schreiner. 1974. *Interindustry Models for Rural Development Research.* Oklahoma State Univ., Agri. Exp. Sta., Tech. Bull. T-139.
11. Flocken, J. D. 1979. Costs of Reclaiming Surface-Mined Lands: Seven County Area of the Ohio Coal Region. Unpublished M.S. Thesis, The Ohio State Univ.
12. Gale, D. 1956. The Closed Linear Model of Production in 'Linear' Inequalities and Related Systems. *In* Kuhn, *et al.,* eds., *Annual Mathematical Studies,* No. 38, Princeton, N. J.
13. Glickman, N. J. 1971. An Econometric Forecasting Model for the Philadelphia Region. *J. Reg. Sci.,* Vol. 2, No. 1.
14. Gowen, Marcia M. 1983. Economics of Wood, Natural Gas, and Coal Fired Boilers Under Alternate Land and Air Pollution Standards: Three Ohio Cases. Unpublished Ph. D. Dissertation, The Ohio State Univ.
15. Hirsch, W. F. 1959. Interindustry Relations of a Metropolitan Area. *Rev. Econ. and Stat.,* 41(4): 360-369.
16. Hushak, L. J., Young K. Ro, and Z. Y. Husain. 1983. An Input-Output Analysis of Regional Economic Development. The Ohio State Univ., Ohio Agri. Res. and Dev. Ctr., Res. Bull. 1155.
17. Jones, C. and S. Stipe. 1978. I-O Definitions. Appendix A *in* U. S. Dept. of Agriculture (USDA), *The Use of Input-Output Analysis.* USDA, Agri. Handbook 530, Washington, D. C.
18. Jones, C. D., Jr. 1978. *Input-Output Analysis Applied to Rural Resource Development Planning.* U. S. Dept. of Agriculture (USDA), Economics, Statistics, and Cooperative Service (ESCS), ESCS-14, Washington, D. C.
19. Jones, L. L., T. L. Sporleader, and G. Mustafa. 1972. Estimation Bias in Regional Input-Output Models Using Secondary Data. *Canadian J. of Agri. Econ.,* Vol. 20, No. 1.
20. Kakish, M. S. 1981. Economic Impacts of Coal Changes and Other Industrial Development: A Regional and County Input-Output Analysis. Unpublished Ph. D. Dissertation, The Ohio State Univ.
21. Kakish, M. S. and G. W. Morse. 1983. Non-Survey Input-Output Analysis: A Tool for Community Development. The Ohio State Univ., Dept. of Agri. Econ. and Rural Sociol., Dept. Series ESO 1050.
22. Leathers, K. L. 1980. *Costs of Strip Mine Reclamation in the West.* U. S. Dept. of Agriculture (USDA), Economics, Statistics, and Cooperative Service, Rural Development Research Report No. 19.
23. LeBlanc, M. R., R. J. Kalter, and R. N. Boisvert. 1978. Allocation of United States Coal Production to Meet Future Energy Needs. *Land Economics,* Vol. 54, No. 3.
24. Leontief, W. W. 1936. Quantitative Input and Output Relations in the Economic System of the United States. *Rev. Econ. and Stat.,* Vol. 18, No. 3.
25. Miernyk, W. H. 1976. Comments on Recent Developments in Regional Input-Output Analysis. *International Regional Science Review,* Vol. 1, No. 2.
26. Miernyk, W. H. 1965. *The Elements of Input-Output Analysis.* Random House, New York, N. Y.
27. Miernyk, W. H., *et al.* 1970. *Simulating Regional Economic Development: An Interindustry Analysis of the West Virginia Economy.* Heath Lexington Books, D. C. Heath and Co., Lexington, Mass.
28. Moore, F. T. and J. W. Peterson. 1955. Regional Analysis: An Interindustry Model of Utah. *Rev. Econ. and Stat.,* Vol. 37, No. 4.
29. Morrison, W. I. and P. Smith. 1974. Nonsurvey I-O Technique at the Small Area Level: An Evaluation. *J. Reg. Sci.,* 14: 1-14.
30. Newman, N. 1972. *The Political Economy of Appalachia: A Case Study in Regional Integration.* D. C. Heath and Co., Lexington, Mass.
31. O'Connor, R. and E. W. Henry. 1975. *Input-Output Analysis and Its Applications.* Hafner Press, Macmillan Publishing Co., Inc., New York, N. Y.
32. Ohio Agricultural Research and Development Center (OARDC). 1979. *1978 Ohio Farm Income.* Ohio

Agri. Res. and Dev. Ctr., Dept. of Agri. Econ. and Rural Sociol., Dept. Series E.S.S. 579.

33. Ohio Bureau of Employment Services (OBES). 1978-1983. *Ohio Labor Market Information.* Various publications for 1977-1983, OBES Series RS 203.1, State of Ohio, Division of Research and Statistics, Columbus.
34. Ohio Bureau of Employment Services (OBES). 1978-1983. *Payrolls and Contributions Under Ohio Unemployment Compensation Law by Industrial Group and by County.* Various publications for 1977-1983, OBES Series RS 203.2, State of Ohio, Division of Research and Statistics, Columbus.
35. Ohio Bureau of Employment Services (OBES). 1978-1981. *Workers Covered Under Ohio Unemployment Compensation Law by Industrial Group and by County.* Various publications for 1978-1980, OBES Series RS 219, State of Ohio, Division of Research and Statistics, Columbus.
36. Ohio Department of Industrial Relations (ODIR). 1970-1980. *Ohio Division of Mines Report.* Various publications for 1969-1979, State of Ohio, Division of Mines, ODIR, Columbus.
37. Palmer, C., N. Bills, and R. Niehaus. 1978. Input-Output Concepts. Chapter IV *in* U. S. Dept. of Agriculture (USDA), *The Use of Input-Output Analysis.* USDA, Agri. Handbook 530, Washington, D. C.
38. Prescott, J. R. and W. C. Lewis. 1975. *Urban-Regional Economic Growth and Policy.* Ann Arbor Science Publishers, Inc., Ann Arbor, Mich.; Halsted Press, John Wiley & Sons, New York, N. Y.
39. Richardson, H. W. 1972. *Input-Output and Regional Economics.* Halsted Press, John Wiley & Sons, New York, N. Y.
40. Richardson, H. W. 1978. The State of Regional Economics: A Survey Article. *International Regional Science Review,* Vol. 3, No. 1.
41. Ritz, P. M. 1979. *The Input-Output Structure of the U.S. Economy, 1972.* Bureau of Economic Analysis (BEA), U. S. Dept. of Commerce (USDC), Washington, D. C.
42. Ro, Young K. 1982. Environmental Regulation and Regional Economic Growth: An Input-Output Analysis of the Ohio Coal Mining Region. Unpublished Ph. D. Dissertation, The Ohio State Univ.
43. Ro, Young K., J. Flocken, and D. L. Forster. 1981. Costs of Reclaiming Ohio Coal Surface Mines. Dept. of Agri. Econ. and Rural Sociol., The Ohio State Univ. (OSU) and Ohio Agri. Res. and Dev. Ctr. (OARDC).
44. Rothblatt, D. N. 1971. *Regional Planning: The Appalachian Experience.* D. C. Heath and Co., Lexington, Mass.
45. Schaffer, W. and K. Chu. 1969. Nonsurvey Techniques for Constructing Interindustry Models. *Papers, Reg. Sci. Assoc.,* 23: 83-104.
46. Schlottman, A. 1977. *Environmental Regulation and the Allocation of Coal: A Regional Analysis.* Praeger Publishers, Inc., New York, N. Y.
47. Schweers, K. and D. Lillie. 1979. Potential Impacts on the Ohio Coal Market of Powerplant Compliance with the Ohio SO_2 Emission Limitations. Memorandum, ICF, Inc., Washington, D. C.
48. Scientific American (SA). 1981. *The Input-Output Structure of the United States Economy.* Scientific American, Inc., New York, N. Y.
49. Shaffer, R. 1979. Estimating Local Income Multipliers: A Review and Evaluation of the Techniques for Ex-Ante Use. *In* Hushak, L. J. and G. Morse, eds., *Proceedings of the Ex-Ante Growth Impact Models Conference,* Iowa State Univ., Ames.
50. Shen, T. Y. 1960. An Input-Output Table with Regional Weights. *Papers and Proceedings, Reg. Sci. Assoc.,* 6: 113-119.
51. Stone, R. and A. Brown. 1962. A Long-Term Growth Model for the British Economy. *In* R. C. Geary, ed., *Europe's Future in Figures.* North McNand Publishing Co., Amsterdam, Holland.
52. Stone, R. and A. Brown. 1965. Behavioral and Technical Change in Economic Models. *In* E. A. G. Robinson, ed., *Problems in Economic Development.* Macmillan Co., New York, N. Y.
53. Temple, Barker and Sloane, Inc. (TBS). 1979. Ohio Section 125 Study: Revised Regional Impact Estimates. Submitted to U. S. Environmental Protection Agency. TBS, Lexington, Mass.
54. Theil, Henri, John C. G. Boot, and Teun Kloek. 1965. *Operations Research and Quantitative Economics: An Elementary Instruction.* McGraw-Hill Book Co., New York, N. Y.
55. Tiebout, C. M. 1962. *The Community Economic Base Study.* Supplementary Paper No. 16, Committee for Economic Development, New York, N. Y.
56. U. S. Dept. of Commerce (USDC). 1979. *The Detailed Input-Output Structure of the U. S. Economy: 1972.* Vol. I, II, and Tape, Bureau of Economic Analysis, USDC, Washington, D. C.
57. U. S. Dept. of Commerce (USDC). 1979. *Statistical Abstract of the United States.* 100th ed., Bureau of the Census, USDC, Washington, D. C.
58. U. S. Dept. of Commerce (USDC). 1974-1979. *Ohio County Business Patterns.* Various publications for 1972-1978, CBP-72, 73, 74, 75, 76, and 77-37, Bureau of the Census, USDC, Washington, D. C.
59. U. S. Dept. of Commerce (USDC). 1980. *1978 County Business Patterns (CBP).* CBP 78-37 and Tape with the state code No. 39, Bureau of the Census, USDC, Washington, D. C.
60. U. S. Dept. of Commerce (USDC). 1981. *Local Area Personal Income, 1974-1979: Summary.* Vol. 1, Bureau of Economic Analysis, USDC, Washington, D. C.
61. U. S. Dept. of Commerce (USDC). 1981. *Local Area Personal Income, 1974-1979: Great Lakes Region.* Vol. 4, Bureau of Economic Analysis, USDC, Washington, D. C.
62. U. S. Dept. of Labor (USDL). 1979. *Time Series Data*

for *Input-Output Industries*. Bull. 2018, Bureau of Labor Statistics, USDL, Washington, D. C.

63. Vaccara, B. N. 1968. Changes Over Time in Input-Output Coefficients for the United States. Paper presented at Fourth International Conference on Input-Output Techniques, Geneva, Switzerland, January 1968. U. S. Dept of Commerce (USDC), Washington, D. C.
64. Yan, C. S. 1969. *Introduction to Input-Output Economics* Holt, Rinehart and Winston, New York, N. Y
65. Young, P C and P. M. Ritz. 1979. *Updated Input-Output Table of the U. S. Economy. 1972* (Derived from the 1967 Input-Output Table). Bureau of Economic Analysis (BEA), Staff Paper No 32, BEA-SP 79-032, BEA, U. S. Dept. of Commerce (USDC), Washington, D C.

APPENDIX A
MATHEMATICAL SPECIFICATION OF THE INPUT-OUTPUT MODEL

The typical flow table can be best expressed by a linear equation system including sets of output equations, input equations, and identity equations:

$$(A1)\quad X_i = \Sigma_{j=1}^{k} x_{ij} + \Sigma_{j=k+1}^{n} f_{ij};\ i=1, \ldots, n$$

$$(A2)\quad X_j = \Sigma_{i=1}^{k} x_{ij} + \Sigma_{i=k+1}^{m} r_{ij};\ j=1, \ldots, m$$

$$(A3)\quad X_i = X_j;\quad i=j;\ i=1, \ldots, k \text{ and } j=1, \ldots, k$$

$$(A4)\quad \Sigma_{i=k+1}^{m} x_i = \Sigma_{j=k+1}^{n} x_j;\ i=k+1, \ldots m;\ j=k+1, \ldots, n$$

where:

X_i = total output of sector i

X_j = total inputs used by sector j

$\Sigma_{j=1}^{k} x_{ij}$ = total intermediate output sold by sector i to itself and to all other endogenous sectors

$\Sigma_{i=1}^{k} x_{ij}$ = total intermediate inputs purchased by sector j from itself and from all other endogenous sectors

$\Sigma_{j=k+1}^{n} f_{ij}$ = total final demand for output of sector i

$\Sigma_{i=k+1}^{m} r_{ij}$ = total primary inputs purchased by sector j from all primary input sectors

Equation A1 shows how the output of a given sector is used by k endogenous intermediate sectors ($\Sigma_{j=1}^{k} x_{ij}$) and n-k exogenous final demand sectors ($\Sigma_{j=k+1}^{n} f_{ij}$). The final demands include household purchases, exports, government purchases, gross inventory accumulation, and gross private capital formation (18, 25, 39). The final demand sectors are the autonomous sectors which determine the level of output of an economy. The final demand sectors in a small economy's I-O model are in general summarized into three sectors: Household, Government, and Export demand sectors; *e.g.*, see Hushak, *et al.* (16). Household and Government sectors are often aggregated further into a single Consumption sector.

Equation A2 shows input purchases by an endogenous sector from all other endogenous sectors ($\Sigma_{j=1}^{k} x_{ij}$) and primary input sectors ($\Sigma_{i=k+1}^{m} r_{ij}$). The primary inputs include payments to households in the form of wages, salaries, rental income, interest income, and profits; payments to government; imports of goods and services; inventory depletion; and capital consumption or depreciation (18, 25). Primary input sectors of a small scale economy's I-O analytical system are commonly aggregated into Labor, Capital, and Imports. The first two sectors are often represented by a single Value Added sector.

The total amount of each primary input employed is subject to the constraint that the total amount of the primary inputs used by the k endogenous sectors be equal to the total amount of the resource available within the economy under consideration; *i.e.*,

$$(A5)\quad \bar{r}_i = \Sigma_{j=1}^{k} r_{ij};\ i=k+1, \ldots, m$$

where $\bar{r}_i$ stands for the total amount of primary input i available within the considered economy.

As an equilibrium condition of the economy under consideration, equation A3 states that total output must be equal in value terms to total inputs for a given endogenous sector. Equation A4 simply shows that total final demand must be equal in value terms to total primary inputs for the entire economy in equilibrium. Equation A4 further implies that as a whole the direct transactions between the final demand and primary input sectors must be in equilibrium. Stated by equations A3 and A4 together then is that for the entire economy in equilibrium, the total input in value terms must be the same as the total output; *i.e.*,

$$\Sigma_{i=1}^{m} X_i = \Sigma_{j=1}^{n} X_j.$$

The Technical Coefficients Matrix

The matrix of the elements x_{ij} in the flow table is called the transactions matrix. From this transactions matrix, the technical coefficient matrix can be defined. The i,jth element of the technical coefficients matrix (a_{ij}) is:

$$(A6)\quad a_{ij} = x_{ij} / X_j;\ i=1, \ldots, k \text{ and } j=1, \ldots, k$$

The technical coefficient indicates what proportion of total inputs used by sector j is purchased from sector i, or it shows direct purchase of a given endogenous sector

from itself and every other endogenous sector per unit of output.

By rewriting equation A6 as $x_{ij} = a_{ij} X_j$, and imposing the identity equation A3, equation A1 can be restated as:

$$(A7) \quad X_i = \Sigma_{j=1}^{k} a_{ij} X_j + \Sigma_{j=k+1}^{n} f_{ij}$$

This equation shows the production relationship in the I-O table using the technical coefficients.

The technical coefficients matrix for primary inputs can be established in a similar way. The element of the technical coefficients matrix for the primary input (v_{ij}) is defined as:

$$(A8) \quad v_{ij} = r_{ij} / X_j ; \quad i=k+1, \ldots, m \text{ and } j=1, \ldots, k$$

It shows the amount of the primary input used as a proportion of total input by the jth endogenous sector. Since equation A8 implies that $r_{ij} = v_{ij} X_j$, it follows from equation A5 that:

$$(A9) \quad \bar{r}_i = \Sigma_{j=1}^{k} v_{ij} X_j ; \quad i=k+1, \ldots, m$$

where $\bar{r}_i$ is the total amount of the primary inputs available to all endogenous and exogenous sectors. Equation A9 states the primary input constraint on the whole economy under consideration in terms of the technical coefficients for primary input use.

The Interdependence Coefficients Matrix

Changes in the final demand have indirect effects in addition to direct effects on the sectoral outputs through successive rounds of transactions based on the interrelation of the endogenous sectors. The technical coefficient shows only the direct effect. The total effect as the sum of the direct and the cumulative indirect effects can be measured by interdependence coefficients.

The interdependence coefficient is defined from the technical coefficients matrix. Equation A7 can be restated in matrix form as:

$$(A10) \quad X = AX + F$$

where:

X = k x 1 column vector of sectoral total outputs (X_i)

A = k x k matrix of technical coefficients (a_{ij})

F = k x 1 column vector of total final demand ($F_i = \Sigma_{j=k+1}^{n} f_{ij}$).

Equation A10 can be restated as:

$$(A11) \quad F = (I - A) X, \text{ or}$$

$$(A12) \quad X = (I - A)^{-1} F, \text{ or}$$

$$(A13) \quad X = BF$$

where I is a k x k identity matrix and B stands for $(I-A)^{-1}$, the k x k interdependence coefficients matrix with elements b_{ij}.

The matrix (I−A) in equation A11 is called the Leontief I-O matrix (25). This matrix is inverted as in equation A12 to obtain a matrix of direct and indirect requirements of intermediate inputs per dollar of final demand. The interdependence coefficient b_{ij} indicates the sum of the final demand change and direct and indirect changes in the requirements of intermediate inputs used by the jth sector as a result of a $1.00 change in final demand of the ith sector. The direct changes in input requirements are given by the technical coefficients matrix A. The indirect changes in input requirements can be obtained as B−(I+A), the total requirements less the initial change in final demand and the direct requirements.

The primary input constraint (equation A9) can also be restated in matrix form as:

$$(A14) \quad R = VX$$

where R is a (m−k) x 1 vector of total primary inputs available and V stands for the (m−k) x k matrix of the technical coefficients for primary input use with elements v_{ij}. Substitution of equation A13 into equation A14 yields:

$$(A15) \quad R = VBF, \text{ or}$$

$$(A16) \quad R = ZF$$

where Z (VB) is the matrix with the elements z_{ij}; i=k+1,m; j=1,k. The element z_{ij} shows the total change (direct and indirect) in the use of primary input i per $1.00 change in final demand for the output of sector j.

Impact Coefficients (Multipliers)

The output multiplier indicates how total production will change throughout the economy as final demand is changed in any one sector of the economy. The output multiplier for a given endogenous sector j is:

$$(A17) \quad \lambda_j^o = \Sigma_{i=1}^{k} b_{ij}$$

The output multiplier for sector j is the sum of the elements in column j of the interdependence coefficients matrix.

The employment multiplier for a given sector indicates total employment changes in the economy resulting from a unit change in direct employment in that sector. The basic assumption underlying the employment multiplier is that, for each endogenous sector, a linear relationship exists between employment and output (18, 39). The employment multiplier is computed from the direct and indirect employment effects estimated via an I-O model. The employment multiplier for a given sector j is:

$$(A18) \quad \lambda_j^u = \{\Sigma_{i=1}^{k} (U_i / X_i) b_{ij}\} / (U_j / X_j)$$

where U is the employment of each endogenous sector.

The denominator in equation A18 is average employment per unit of output in sector j, or the direct employment effect per unit change in final demand. The

numerator is the sum of interdependence coefficients for sector i weighted by average employment per unit of output in each endogenous sector (10).

The most common I-O employment multipliers are the Type I and Type II. The employment multiplier defined here is the Type I. The Type II employment multiplier is the ratio of direct, indirect, and induced employment effects resulting from a unit change in final demand to direct effects. The direct, indirect, and induced employment effects are estimated by multiplying the column vector of the interdependence coefficients matrix with the household sector endogenous by a row vector of average employment per unit of output in each endogenous sector. The direct and indirect effects for the Type I multiplier are estimated on the basis of the interdependence coefficients matrix with the household sector exogenous. For more details, see Jones (18), Palmer, *et al.* (37), Richardson (39), and Miernyk (25).

The income multiplier measures the total change in income throughout the economy resulting from a unit change in income in a given sector in response to a final demand change. The basis of the income multiplier is that a certain amount of income is generated with each change in the output of each endogenous sector (18). The income multiplier for a given sector j is the ratio of total (direct plus indirect) income effect to direct income effect resulting from a change in final demand:

$$(A19) \quad \lambda_j^y = \{\Sigma_{i=1}^{k} (Y_i / X_i)\, b_{ij}\} / (Y_j / X_j)$$

where Y is income of individual endogenous sectors.

The direct income coefficient for sector j, the denominator in equation A19, is the average income per unit of output in sector j. The total (direct plus indirect) income effect, the numerator in equation A19, is obtained by multiplying the column vector of the direct input coefficients by average income for each sector (10).

There are Type I and Type II income multipliers which are similar to Type I and Type II employment multipliers. The income multiplier defined in equation B19 is the Type I multiplier. The Type II income multiplier is the ratio of the direct, indirect, and induced income effects resulting from a unit change in final demand to the direct income effect. The Type I income multiplier is computed from the interdependence coefficients matrix with the household sector exogenous, while the Type II multiplier is estimated from the interdependence coefficients matrix with the household sector endogenous. For details, see Richardson (39) and Jones (18).

Price Adjustment

Problems of the I-O model's static nature can be reduced through the price adjustment on the technical coefficients matrix. The out-of-date technical coefficients matrix (A_o) can be updated to a matrix for time t (A_t) by pre-multiplying by a diagonal matrix of price indices (P) for all endogenous sectors and post-multiplying by a diagonal matrix of the reciprocals of the price indices (P^{-1}) (51):

$$(A20) \quad A_t = PA_oP^{-1}$$

This relative price adjustment multiplies each row by the price index for sector i and each column by the inverse of the price index for sector j. As a result of this adjustment, each technical coefficient (a_{ij}) is increased by the increased cost of purchasing from sector i (p_i) and decreased by the increased value of the output for sector j ($1/p_j$); *i.e.*,

$$a_{ij}^t = p_i\, a_{ij}^o\, (i / p_j).$$

In this price adjustment, it is assumed that price differences operate uniformly along rows (9), that substitution of one product for another operates uniformly along the rows (9, 52), and that changes in the production function operate uniformly along the columns (51, 52).

APPENDIX B
REGIONAL I-O MODEL: EMPIRICAL GENERATION

The regional I-O model of 15 major coal producing counties in Ohio is derived from the 1978 U.S. national I-O model updated from the 1972 model. Presented are the detailed step-by-step procedures of this derivation. The overall presentation follows the sequential order of research procedures visualized in Fig. B-1.

Selection of Economic Sectors (Step 1)

Industries reported in the 1978 Ohio County Business Patterns data for the study region are grouped into 24 endogenous sectors according to the following two categories: 1) industries producing similar and closely related products, and 2) the conformity with the level of aggregation used by the Bureau of Economic Analysis (BEA) in preparing the U.S. national I-O model for 1972. With the subdivision of the coal mining sector into underground and surface coal mining sectors, the

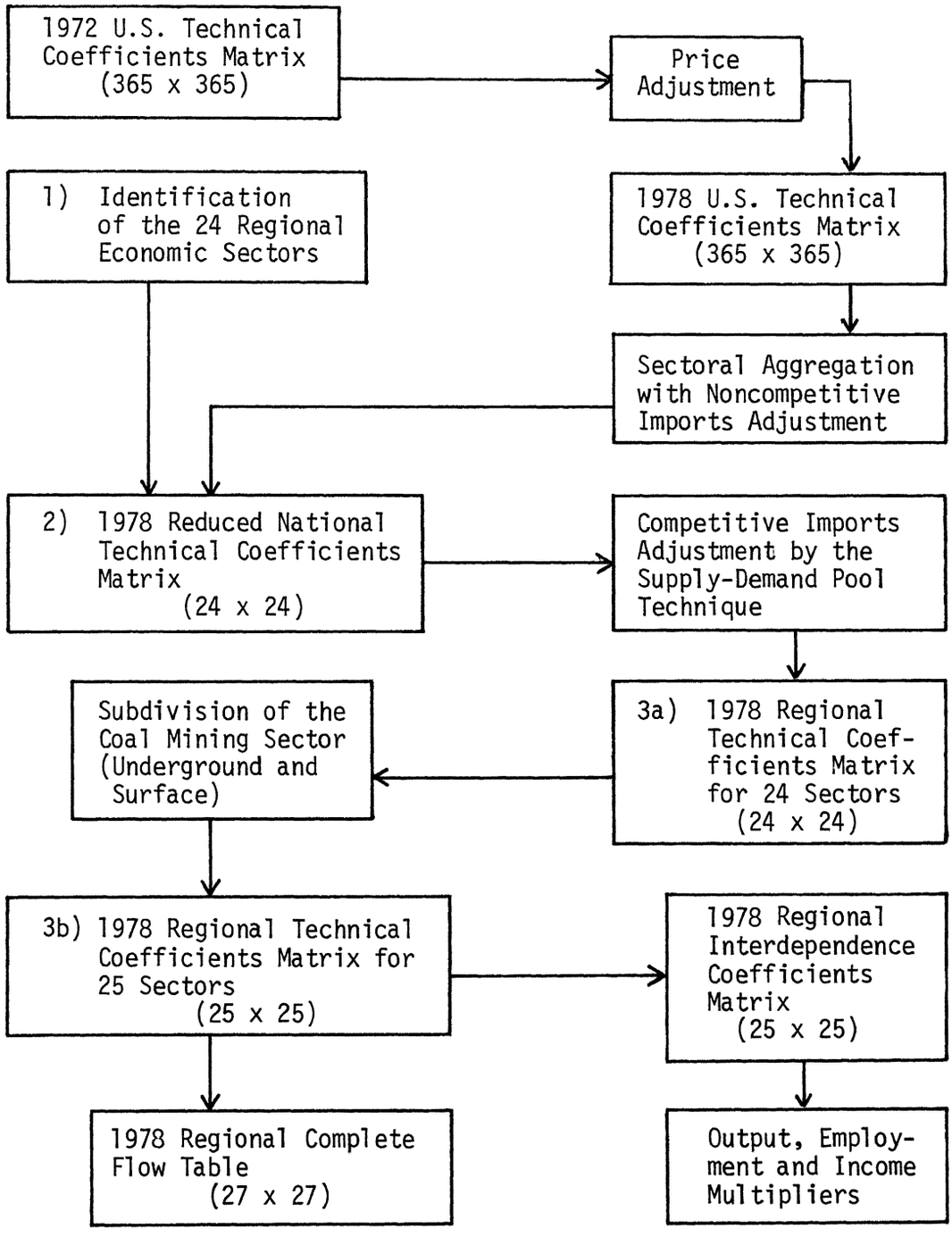

FIG. B-1.—The research procedures.

economy of the study region is subdivided into a total of 25 endogenous sectors. These regional endogenous sectors are listed in Table B-I.

In addition to the 25 endogenous sectors listed in Table B-I, the regional I-O model in this study includes value added and imports as the primary input sectors and consumption and exports as the final demand sectors. Entries for the primary input sectors are wages, value added, and imports, respectively. Private purchases and purchases by federal, state and local governments are the elements of the consumption demand vector. Exports are defined as residuals.

Reduced National Input-Output Model (Step 2)

The most recent national technical coefficients matrix is for 1972 at two different Standard Industrial Classification (SIC) levels: 2-digit and 4-digit. The matrix at the 2-digit SIC level includes 85 endogenous sectors (41) or 97 endogenous sectors (48), and the matrix at the 4-digit SIC level includes 496 endogenous sectors (56) or 365 endogenous sectors. The 365 sector matrix is not published but is available on computer readable magnetic tape.

The major problem in deriving the regional technical coefficients from the national ones is product and industry mix (26, 39). This problem is attributable to the possible differences between regional and national production functions and between regional and national industrial compositions. The differences in the production functions, according to Boisvert and Bills (3), can possibly be corrected by using highly disaggregated national coefficients, because the input structure of industries at the 4-digit SIC level is more similar throughout the nation than at the 2-digit SIC level; see also Miernyk (25). At the 4-digit SIC level of sectoral disaggregation, the national coefficients reflect more reliable regional coefficients. Two recent empirical comparisons between I-O models derived from the 2-digit SIC national model and the 4-digit SIC national model with regional survey models confirm this (5, 6). For this reason, the present study uses the U.S. national coefficients at the 4-digit SIC level. In his recent study, Kakish (20) updated the 1972 U.S. national coefficients for 365 sectors at the 4-digit SIC level to 1978. These updated national coefficients are available for the present study on computer readable magnetic tape. The updating procedure was discussed earlier. For the price indices used in the price adjustment, see Appendix A in Ro (42).

The difference in the industrial composition between regional and national economies, on the other hand, can be partially corrected by making an adjustment on

TABLE B-I.—Endogenous Sectors Included in the Regional Input-Output Model for the 15 Major Coal Producing Counties in Ohio.

Sector	Bureau of Economic Analysis Classification	Standard Industrial Classification	West Virginia Study Classification
1 Agriculture	1-4	1, 2, 7-9	1
2 Coal Mining	7	11, 12	N/A*
Underground	7	11, 12	2
Surface	7	11, 12	3
3 All Other Mining	8, 9	13, 14	4, 5
4 Construction	11, 12	15-17	6-8
5 Food and Kindred Products	14	20	9-12
6 Textile and Apparel	17-19	21-23	13
7 Lumber and Wood Products	20-25	24-26	14, 15
8 Printing and Publishing	26	27	16
9 Chemicals and Plastics	27-32	28-31	17, 18
10 Stone, Clay, and Glass	35, 36	32	19-20
11 Primary Metals	37, 38	33	21
12 Fabricated Metals	39-42	34	22
13 Mechanical Machinery	43-52	35	23
14 Electrical Machinery	53-58	36	24
15 Instruments and Equipment	59-64	37-39	25-27
16 Transportation and Warehousing	65	40-42, 44-47	42-44
17 Communications	66, 67	48	45
18 Utilities	68	49	46-48
19 Wholesale Trade	69	50, 51	29
20 Retail Trade	69	52-59, 73, 80	30-32
21 Finance, Insurance, and Real Estate	70, 71	60-66	33-37
22 Services	72-77, 81	58, 70-73, 75 76, 78-84, 89	28, 38-41
23 Federal Government	78	N/A	N/A
24 State and Local Government	79	N/A	N/A

Sources: Various publications of the Ohio Bureau of Employment Services for 1978 (33), (36, 59), Appendix B in Ritz (41), Table A in Young (65), (41), and (60).
*N/A = Not Applicable

the national technical coefficients with regional weights representing the importance of individual sectors in the region. The use of some measure of gross output or value added is considered to be ideal in this weighting scheme, but figures on regional gross output and value added at the 4-digit SIC level are not available in practice, and the weighting scheme often relies exclusively on disaggregated employment data (3, 50). The present study uses regional employment as regional weights in computing the regional technical coefficients from the national coefficients.

Except for agricultural employment, the 1978 regional employment figures are available at the 4-digit SIC level in USDC (59). Agricultural employment is estimated as regional agricultural output divided by national per capita agricultural productivity. The 1978 data on regional agricultural output and national per capita agricultural productivity are available at the 4-digit SIC level in OARDC (32) and USDC (57), respectively. For the complete figures on the 1978 regional employment, see Appendix B in Ro (42).

In order to obtain the regional technical coefficients, the 365-sector matrix of the U.S. national technical coefficients is aggregated to the 24 endogenous sectors identified in the region (Table B-I). The theoretical rationale and the computer program used in this study are described more fully in Kakish and Morse (21). For those sectors with zero employment, the technical coefficient is transferred to the import row as a noncompetitive import. Of the 365 endogenous sectors of the U.S. national economy, 118 sectors had zero production in the region in 1978. The intermediate inputs from these 118 sectors are excluded from the regional transactions and allocated directly to regional imports.

The national technical coefficients for the remaining 247 endogenous sectors are aggregated following the conventional two steps: the aggregation by columns and then rows (3, 21). The technical coefficients for a number of individual sectors in the original national matrix (a^*_{gq}) are aggregated by columns, weighting each sector by employment at the 4-digit SIC level (U_q):

$$(B1)\quad a^*_{gj} = \Sigma_{q\varepsilon\sigma_j} a^*_{gq} \left(U_q / \Sigma_{q\varepsilon\sigma_j} U_q\right),\ \sigma_j \varepsilon \sigma$$

where σ is the set of 247 endogenous sectors, and σ_j is a subset of σ. This aggregation of a number of columns into one column results in a new non-square matrix (247 x 24) of the national technical coefficients. The second step aggregates the rows in the non-square matrix (247 x 24) to yield a square matrix (24 x 24):

$$(B2)\quad a^*_{ij} = \Sigma_{g\varepsilon\sigma_i} a^*_{gj},\ \sigma_i = \sigma_j,\ \sigma_i \varepsilon \sigma$$

This reduced matrix of the national technical coefficients reflects the difference between regional and national industrial composition when it is used in computing the regional technical coefficients matrix (3). While this matrix has been adjusted for noncompetitive imports, it has not been adjusted for competitive imports. Some of the regional technical coefficients need to be adjusted downward to reflect the fact that regional output is inadequate to service all of the intermediate demand and final demand. This is done in Step 3.

Complete Regional I-O Model (Step 3)

Regional Sectoral Output

In order to generate the regional transactions matrix, complete information on the outputs of all endogenous sectors in the region is needed. Published data provide sectoral outputs for the agriculture and coal mining sectors only. For the remaining sectors, sectoral outputs (X_i) are computed on the basis of the regional sectoral employment (U_i) and national sectoral average productivity of labor as the national sectoral outputs (X^*_i) divided by the national sectoral employment (U^*_i); *i.e.;*

$$(B3)\quad X_i = X_j = U_i \left(X^*_i / U^*_i\right), \qquad i=j$$

This procedure was suggested by Jones, *et al.* (19).

Equation B3 provides more precise estimates of sectoral outputs of the regional economy if it is applied to highly disaggregated information on output and employment. The 1978 information on the national output is available only at the 2-digit SIC level, however. For this reason, equation B3 is estimated on the basis of the 1972 national output and employment figures available at the 365-sector level. The estimation includes three steps. First, the 1972 national productivities of labor are computed for the 365 sectors and then updated to 1978. The 1972 national output figures are available in USDC (56). The 1972 national employment figures are available from various sources; see Appendix B in Ro (42).

Second, the 1978 regional outputs for the 365 sectors are defined as the regional sectoral employment multiplied by the 1978 national sectoral productivity. Finally, these computed outputs are aggregated for a total number of 24 endogenous sectors of the regional economy.

Regional Sectoral Income

Information on income by sector is also not available from the published data. Sectoral incomes for all endogenous sectors within the region (Y_i) are estimated as the regional sectoral employment (U_i) multiplied by the sectoral average annual wage rates or per capita average annual earnings (W_i):

$$(B4)\quad Y_i = U_i W_i$$

The sectoral per capita average annual earnings are obtained from information on the sectoral per capita average weekly earnings provided in OBES (34) and presented in Appendix Table B-II. Figures on the average annual earnings assume 52 weeks per year and 40 hours per week.

Regional Total Consumption Demand

Information on regional consumption demand is not directly available from published data. Consumption demand is the total final demand with export demand excluded. This includes household consumption de-

mand and government consumption demand representing all other consumption demands than exports. Regional total household consumption demand ($f._h$) is estimated as the national total household consumption demand ($f._h^*$) multiplied by the ratio of regional total to national total per household income:

$$(B5) \quad f._h = f._h^* \left(\Sigma_{i=1}^{m} Y_i \,/\, \Sigma_{i=1}^{m} Y_i^*\right)$$

Similarly, regional total government consumption demand ($f._g$) is the national total government consumption demand ($f._g^*$) multiplied by the ratio of regional total to national total output:

$$(B6) \quad f._g = f._g^* \left(\Sigma_{i=1}^{m} X_i \,/\, \Sigma_{i=1}^{m} X_i^*\right)$$

The sum of these two different consumption demands defines the regional total consumption demand other than exports ($f..$)

$$(B7) \quad f.. = f._h + f._g$$

The 1978 information on the national final demand is obtained by updating the 1972 information available in USDC (56).

Regional Technical Coefficients Matrix (Step 3a)

At this point the reduced matrix of the national technical coefficients does not contain the noncompetitive imports, but it still contains the competitive imports in its elements. The competitive imports are the regional goods and services imported from outside the region due to the region's insufficient production capacity. The regional technical coefficients matrix is obtained from the reduced national matrix by adjusting these competitive imports through the application of the supply-demand pool technique.

The supply-demand pool technique is a method of generating the regional technical coefficients from the national ones on the basis of the concept of commodity balance of the regional economy under consideration.

TABLE B-II.—1978 U. S. National per Capita Productivity Indices (1972 = 100 and 1978 per Capita Average Annual Earnings in the Region at the 25-Sector Level of Disaggregation.*

Regional Endogenous Sector	1978 National Productivity Index			Regional per Capita Average Annual Earnings†† (1978 $)
	1972 Productivity† (1972 $)	1978 Productivity‡ (1978 $)	1978 Index** (1972 = 100)	
Agriculture	23,121	35,172	152.1	8,129
Coal Mining	33,805	55,199‡‡	163.3	19,865‡‡
Underground	N/A	29,133‡‡	N/A	19,362‡‡
Surface	N/A	88,524‡‡	N/A	20,388‡‡
All Other Mining	66,023	86,260	130.6	14,166
Construction	36,598	59,906	163.7	17,106
Food and Kindred Products	69,196	130,548	188.7	13,059
Textile and Apparel	26,451	43,205	163.3	9,961
Lumber and Wood Products	32,429	54,856	169.2	13,051
Printing and Publishing	15,449	37,060	239.9	13,520
Chemicals and Plastics	49,456	126,209	255.2	15,338
Stone, Clay, and Glass	31,053	47,960	154.4	14,413
Primary Metals	45,120	94,870	210.3	18,633
Fabricated Metals	33,013	56,674	171.7	14,767
Mechanical Machinery	33,729	51,486	152.6	15,363
Electrical Machinery	28,333	43,024	151.9	13,509
Instruments and Equipment	44,307	55,054	124.3	14,709
Transportation and Warehousing	28,539	49,381	173.0	16,097
Communications	26,222	35,861	134.7	16,187
Utilities	80,196	133,661	166.7	17,046
Wholesale Trade	25,257	33,802	133.8	13,904
Retail Trade	8,290	13,101	158.0	8,524
Finance, Insurance, and Real Estate	65,783	73,514	111.8	10,883
Services	22,022	32,132	145.9	9,953
Federal Government	10,775	16,378	152.0	18,235***
State and Local Government	5,321	8,087	152.0	11,176

*The figures assume 52 weeks per year and 40 hours per week.
Sources: †(56) and Appendix B of Ro (42).
‡Appendix A (56) and (61).
**1978 productivity divided by 1972 productivity.
††(33—1978 and 1979), (34—1979), and (35—1978, 1979).
‡‡(36).
***(59).

This approach begins by finding an initial estimate of regional transactions (x_{ij}) as the product of the regional total input in a given sector j (X_j), equation B6, and the national technical coefficients (a^*_{ij}); *i.e.*,

$$(B8) \quad \hat{x}_{ij} = a^*_{ij} X_j$$

The regional consumption demand vector ($f_{i.}$) is estimated as the region's share of the nation's consumption demand vector

$$(B9) \quad \hat{f}_{i.} = f^*_{i.} \ (f_{..}/f^*_{..})$$

where $f_{..}$ and $f^*_{..}$ stand for the total regional and national consumption demand, respectively, and $f^*_{i.}$ is the national consumption demand for the output of sector i. In this expression, $f_{i.}$ is defined as the estimated regional consumption demand for the output of sector i.

The commodity balances for individual industries within the region (e_i) can be estimated as:

$$(B10) \quad \hat{e}_i = X_i - \hat{X}_i$$

where X_i are the estimates of the regional output requirements from an individual sector i; *i.e.*

$$\hat{X}_i = \Sigma_{j=1}^{k} \hat{x}_{ij} + \hat{f}_{i.}$$

When the commodity balance is positive or zero (*i.e.*, $e_i \geq 0$), imports are assumed to be zero and the regional technical coefficients are set equal to the national ones ($a_{ij} = a^*_{ij}$). Regional transactions are set equal to the initial estimates ($x_{ij} = x^*_{ij}$) and exports are set equal to the estimated commodity balances ($e_i = e_i$).

If the commodity balance of the ith sector is negative ($e_i < 0$), the region is assumed to import a part of its input needs for sector i, and the regional technical coefficients (a_{ij}) are set equal to:

$$(B11) \quad a_{ij} = a^*_{ij} \ (X_i / \hat{X}_i).$$

The ratio $(X_i/X_i) < 1$ when $e_i < 0$ from equation B10.

Further consequences of the adjustment by equation B11 are:

$$(B12) \quad x_{ij} = a_{ij} X_j$$

$$(B13) \quad e_i = 0$$

$$(B14) \quad \pi_{ij} = \hat{x}_{ij} - x_{ij}$$

where π_{ij} are sectoral imports from sector i by endogenous sectors.

Subdivision of Coal Mining Sector (Step 3b)

The column elements of the technical coefficients matrix for the surface coal mining sector within the study region (a_{is}) are estimated from the column elements of the regional technical coefficients matrix for the pre-divided coal mining sector (a_{ic}) as:

$$(B15) \quad a_{is} = a_{ic} \ (X_c / X_s) \ (a^w_{is} / \{a^w_{is} + a^w_{iu}\})$$

TABLE B-III.—Relative Importance of the Elements in Columns of Technical Coefficients Matrix for the Underground and Surface Coal Mining Sectors in the West Virginia Input-Output Model.

	Total	Underground	Surface
Agriculture	100.0	42.860	57.140
Underground Coal Mining	100.0	4.945	95.055
Surface Coal Mining	100.0	4.632	95.368
All Other Mining	100.0	68.000	32.000
Construction	100.0	99.546	0.454
Food and Kindred Products	100.0	100.000	0.000
Textile and Apparel	100.0	42.860	57.140
Lumber and Wood Products	100.0	94.567	5.433
Printing and Publishing	100.0	97.500	2.500
Chemicals and Plastics	100.0	100.000	0.000
Stone, Clay, and Glass	100.0	100.000	0.000
Primary Metals	100.0	100.000	0.000
Fabricated Metals	100.0	27.778	72.222
Mechanical Machinery	100.0	43.307	56.693
Electrical Machinery	100.0	0.000	100.000
Instruments and Equipment	100.0	97.980	2.020
Transportation and Warehousing	100.0	16.979	83.021
Communications	100.0	28.045	71.955
Utilities	100.0	92.260	7.740
Wholesale Trade	100.0	39.705	60.295
Retail Trade	100.0	60.833	39.167
Finance, Insurance, and Real Estate	100.0	2.891	79.109
Services	100.0	10.585	89.415
Federal Government	100.0	42.860	57.140
State and Local Government	100.0	42.860	57.140

Source: Computed on the basis of the technical coefficients for the underground and surface coal mining sectors in the 1965 West Virginia I-O model.

where X_c is the output of the pre-divided coal mining sector ($X_c = X_s + X_u$) and a^w_{is} and a^w_{iu} are the technical coefficients from the West Virginia model for the surface and underground coal mining sectors, respectively. The ratio X_c / X_s adjusts a_{ic} so that a_{is} reflects the difference between X_c and X_s while maintaining the constraint that $\Sigma^m_{i=1} a_{is} = 1$. The column elements for the underground coal mining sector (a_{iu}) are estimated in the same way; *i.e.*,

$$a_{iu} = a_{ic} (X_c / X_u) (a^w_{iu} / \{a^w_{is} + a^w_{iu}\}).$$

The technical coefficients for the underground and surface coal mining sectors in the 1965 West Virginia model are used in computing the ratio of the technical coefficients for the underground or surface coal mining sector to the pre-divided coal mining sector's technical coefficients. In this computation, updating is not necessary because the price adjustment by equation A20 does not affect the relative importance of the technical coefficients between the underground and surface coal mining sectors. Appendix Table B-III presents the computed ratios for individual sectors.

Since the outputs of the underground and surface coal mining sectors are identical (*i.e.*, coal is coal), the relative importance between the two coal mining sectors' outputs, in addition to the technical information from the West Virginia model, is also used in the row division. The row elements of the technical coefficients matrix for the surface coal mining sector (a_{sj}) are estimated as the row elements of the technical coefficients matrix for the predivided coal mining sector (a_{cj}) adjusted by the average values of the two ratios X_s / X_c and $a^w_{sj} / (a^w_{sj} + a^w_{uj})$; *i.e.*,

$$(B16) \quad a_{sj} = a_{cj} \frac{1}{2} (\{X_s / X_c\} + \{a^w_{sj} / (a^w_{sj} + a^w_{uj})\}).$$

The computed average values of the two ratios X_s/X_c and $a^w_{sj}/(a^w_{sj} + a^w_{uj})$ for individual sectors are presented in Appendix Table B-IV.

The row elements of the technical coefficients matrix for the underground coal mining sector can be estimated in the same way, or by subtracting the estimated technical coefficients for the surface coal mining sector from the technical coefficients for the pre-divided coal mining sector; *i.e.*,

$$a_{uj} = a_{cj} \frac{1}{2} (\{X_n / X_c\} + \{a^w_{uj} / (a^w_{sj} + a^w_{uj})\}),$$
$$\text{or } a_{uj} = a_{cj} - a_{sj}.$$

No problem is caused in the row or column division by the difference between the underground and surface coal mining sectors' imports. The technical coefficients for the pre-divided coal mining sector in the study region's I-O model and the technical coefficients for the underground and surface coal mining sectors in the West Virginia I-O model do not contain any components of regional imports.

TABLE B-IV.—Percentage Distribution Used in the Row Division of Coal Mining Sector into the Underground and Surface Coal Mining Sectors in the Regional Input-Output Model.

	Total	Underground	Surface
Agriculture	100.00	64.805	35.195
Underground Coal Mining	100.00	37.145	62.855
Surface Coal Mining	100.00	35.557	64.443
All Other Mining	100.00	21.430	78.779
Construction	100.00	52.221	47.779
Food and Kindred Products	100.00	47.208	52.792
Textile and Apparel	100.00	64.805	35.195
Lumber and Wood Products	100.00	64.805	35.195
Printing and Publishing	100.00	50.519	49.481
Chemicals and Plastics	100.00	64.805	35.195
Stone, Clay, and Glass	100.00	59.805	40.195
Primary Metals	100.00	64.805	35.195
Fabricated Metals	100.00	64.805	35.195
Mechanical Machinery	100.00	64.805	35.195
Electrical Machinery	100.00	29.610	70.390
Instruments and Equipment	100.00	27.541	72.459
Transportation and Warehousing	100.00	53.073	46.927
Communications	100.00	64.805	35.195
Utilities	100.00	59.969	40.031
Wholesale Trade	100.00	64.805	35.195
Retail Trade	100.00	44.601	55.399
Finance, Insurance, and Real Estate	100.00	34.982	65.018
Services	100.00	49.927	50.073
Federal Government	100.00	29.610	70.390
State and Local Government	100.00	29.610	70.390

Source: Computed on the basis of the technical coefficients for the underground and surface coal mining sectors in the 1965 West Virginia I-O model and the output ratio of the underground and surface coal mining sectors in the study region.

Output to / Input from			PURCHASING SECTORS: Intermediate Demand* 1	. .	12	. .	25	Final Demand: Consumption† 26	Exports‡ 27	Gross Outputs
PRODUCING SECTORS	Intermediate Inputs	1	$x_{1,1}$		$x_{1,12}$		$x_{1,25}$	$\hat{f}_{1.}$	$\hat{e}_1$	X_1
		.	.		.		.	.	.	.
		12	$x_{12,1}$		$x_{12,12}$		$x_{12,25}$	$\hat{f}_{12}$	$\hat{e}_{12}$	X_{12}
		.	.		.		.	.	.	.
		25	$x_{25,1}$		$x_{25,12}$		$x_{25,25}$	$\hat{f}_{25}$	$\hat{e}_{25}$	X_{25}
	Primary Inputs: Value Added**	26	$va_{26,1}$		$va_{26,12}$		$va_{26,25}$			X_{26}
	Primary Inputs: Imports††	27	$\hat{e}_{27,1}$		$\hat{e}_{27,12}$		$\hat{e}_{27,25}$			X_{27}
Gross Outlays			X_1	. . .	X_{12}	. .	X_{25}	X_{26}	X_{27}	$\sum_{i=1}^{27} X_i$

* $c_{ij} = a_{ij} X_j$

† $\hat{f}_{i.} + f_{ih} + f_{ig}$

‡ $\hat{e}_{i27} = \hat{e}_i$ for $\hat{e}_i > 0$

** $va_{26j} = X_j - \sum_{i=1}^{25} x_{ij} - \hat{e}_{27j}$

†† $\hat{e}_{27j} = -\hat{e}_i$ for $\hat{e}_i \leq 0$

FIG. B-2.—The complete regional flow table.

Complete Regional Flow Table

The final consequence of the above research procedures is the complete flow table of the regional I-O model for the 15 major coal producing counties in Ohio (Appendix Figure B-2). The table is arranged in a 27 x 27 square matrix form. The column arrangement includes 25 purchasing sectors and the 2 final demand sectors, consumption and exports. The row arrangement includes 25 producing sectors and the 2 primary input sectors, value added and imports. Entries to the two final demand vectors are the regional consumption demand ($f_{i.}$) and positive regional commodity balances ($e_i > 0$), respectively. The negative regional commodity balances ($e_i < 0$) as competitive imports are the entries in the regional import vector. Noncompetitive imports are also allocated to this regional import vector. Entries to the value added vector are the regional sectoral total inputs less the sum of the regional sector imports and intermediate inputs. The last column and row represent the regional sectoral total outputs and inputs, respectively.

Estimation of Environmental Impacts

The impacts of sulfur emission control and reclamation requirements on the regional economy can be explained in terms of changes in the region's output, employment, and income due to changes in the final demand for coal. The value of an output change in the regional economy (ΔX) resulting from a unit change in the coal mining sector's final demand can be estimated by multiplying the sector's change in final demand (ΔF_c) by the output multiplier for that sector (λ_c^o); *i.e.*,

$$(B17) \quad \Delta X = \lambda_c^o \Delta F_c$$

Similarly, the value of a regional change in employment (ΔU) or income (ΔY) due to a unit change in the coal mining sector's final demand can be estimated as:

$$(B18) \quad \Delta U = \Delta F_c \, (U_c / X_c) \, \lambda_c^u$$

$$(B19) \quad \Delta Y = \Delta F_c \, (Y_c / X_c) \, \lambda_c^y$$

where the subscript c stands for the underground or surface coal mining sector, and the superscripts u and y designate employment and income multipliers, respectively. These equations provide estimates of total effect of changes in final demand for coal on the regional economy as a whole.

The effect of a final demand change in the coal mining sector on individual sectors of the region's economy (ΔX_i) can be estimated as the coal mining sector's column elements of the interdependence coefficients matrix (b_{ic}) multiplied by a final demand change in the coal mining sector (ΔF_c); *i.e.*,

$$(B20) \quad \Delta X_i = b_{ic} \, \Delta F_c$$

The sum of ΔX_i is the same as the total change estimated by equation B17. The effect of a final demand change in the coal mining sector on individual sectors in terms of employment (ΔU_i) and income (ΔY_i) can be estimated as:

$$(B21) \quad \Delta U_i = b_{ic} \, (U_i / X_i) \, \Delta F_c$$

$$(B22) \quad \Delta Y_i = b_{ic} \, (Y_i / X_i) \, \Delta F_c$$

where the subscript c stands for the underground or surface coal mining sector. As in the case of output, the sum of ΔU_i and ΔY_i is equal to the total change estimated by equations B18 (ΔU) and B19 (ΔY), respectively.

Sulfur regulations affect the demand for both the underground and surface mined coal, while reclamation regulations influence only surface mined coal. In order to estimate economic impacts of sulfur regulations, equations B20, B21, and B22 are applied to both the underground and surface coal mining sectors. The same equations are applied to only the surface coal mining sector to estimate economic impacts of reclamation requirements.

APPENDIX C

TABLE C-I.—1978 Regional Flow Table for the 15 Coal Producing Counties in Ohio.

	AGRICULT	UNDECOAL	SURFCOAL	OTMINING	CONSTRUC
AGRICULT	57172.1	0.0	0.0	2.6	758.7
UNDECOAL	6.3	1481.8	28465.5	22.8	0.0
SURFCOAL	3.4	2507.4	51591.3	83.6	0.0
OTMINING	274.3	110.5	52.0	9227.0	4043.0
CONSTRUC	1770.8	2841.4	13.0	5323.0	138.5
FOODKIND	27087.3	13.3	0.0	13.4	47.6
TEXTILES	94.9	46.4	61.8	27.0	1061.9
LUMBERWD	1449.2	910.0	52.2	348.0	32722.7
PRINTING	163.8	64.6	1.7	52.3	137.9
CHEMICAL	16190.0	15309.1	0.0	7541.5	26899.0
STONECGL	117.2	1949.4	0.0	64.0	32650.2
PRMETALS	43.5	5862.2	0.0	3680.5	20072.3
FAMETALS	1827.2	927.2	4850.8	1794.6	57285.7
MEMACHIN	2238.8	11014.5	14409.5	8617.4	12511.9
ELMACHIN	149.2	0.0	1006.1	1089.0	12624.3
INSTRUME	324.1	346.6	7.1	572.1	2011.4
TRANSPOT	4362.3	304.8	1489.4	1062.0	7117.5
COMUNICA	484.7	57.9	148.5	243.3	901.3
UTILITES	2744.1	8563.9	718.0	5686.1	796.7
WHOLSALE	5980.8	2881.9	4373.5	1785.0	13903.7
RETAILTR	659.6	105.3	67.7	150.9	13881.1
FINANINS	7370.9	249.1	8362.7	11744.6	3152.9
SERVICES	6359.1	1339.5	11308.0	7809.2	31887.3
FEDLGOVT	43.1	63.4	84.5	83.4	114.7
S&LOGOVT	8.0	43.1	57.4	121.8	29.7
VALADDED	163431.2	143517.5	345102.7	208812.9	274248.8
PIMPORTS	47287.3	7554.5	18654.2	14826.5	45186.4
TOTINPUT	347701.0	206522.0	490862.0	290716.0	594558.0

	FOODKIND	TEXTILES	LUMBERWD	PRINTING	CHEMICAL
AGRICULT	217333.7	410.2	77.0	18.8	480.7
UNDECOAL	122.9	5.2	697.1	1.7	1185.5
SURFCOAL	137.4	2.8	378.6	1.7	643.8
OTMINING	23.9	0.0	100.7	0.0	25090.2
CONSTRUC	1224.3	69.0	1384.0	406.9	4373.9
FOODKIND	107555.4	40.3	32.2	20.4	4221.1
TEXTILES	122.8	6101.6	451.1	37.5	448.9
LUMBERWD	25336.3	754.8	80285.9	18905.9	29359.1
PRINTING	4428.3	62.6	228.7	8104.0	1415.5
CHEMICAL	14602.2	3813.2	20543.2	3355.7	253412.9
STONECGL	8039.3	1.2	1534.6	4.2	5516.8
PRMETALS	397.1	24.0	15197.6	231.0	12479.9
FAMETALS	17242.6	84.1	12555.9	199.2	23724.6
MEMACHIN	1390.7	145.0	1622.6	468.3	11764.7
ELMACHIN	26.4	2.7	42.9	5.4	847.8
INSTRUME	186.2	13.7	292.3	137.2	2153.0
TRANSPOT	6893.3	1052.4	4660.3	2129.7	20057.3
COMUNICA	849.4	257.0	564.3	774.8	2321.7
UTILITES	6276.2	687.8	6425.8	913.7	21141.8
WHOLSALE	19276.8	2703.9	9467.1	1874.8	19186.1
RETAILTR	267.8	28.1	104.0	80.9	306.7
FINANINS	3157.0	963.4	3372.6	1461.1	8537.8
SERVICES	23044.3	3567.1	11787.3	8300.3	45852.1
FEDLGOVT	575.9	187.3	261.2	475.8	906.2
S&LOGOVT	89.8	4.1	99.2	10.8	163.4
VALADDED	211224.4	25815.1	144871.6	76317.0	427162.8
PIMPORTS	121108.0	47218.6	52915.9	6264.3	137945.9
TOTINPUT	823864.0	94061.0	370041.0	130506.0	1061122.0

TABLE C-I (continued).—1978 Regional Flow Table for the 15 Coal Producing Counties in Ohio.

	STONECGL	PRMETALS	FAMETALS	MEMACHIN	ELMACHIN
AGRICULT	56.6	352.2	242.6	63.4	28.0
UNDECOAL	806.2	46995.1	306.1	147.7	21.3
SURFCOAL	541.9	25522.6	166.3	80.2	50.7
OTMINING	13279.0	154121.5	599.6	19.7	112.4
CONSTRUC	2002.3	25864.5	1906.0	2025.2	1443.1
FOODKIND	15.0	111.4	62.1	179.0	47.5
TEXTILES	27.0	499.8	217.8	155.9	169.3
LUMBERWD	9472.5	15209.8	11912.7	5268.7	9132.8
PRINTING	419.9	2387.4	1849.8	861.8	508.3
CHEMICAL	22442.5	86526.2	24468.4	17604.2	26378.1
STONECGL	15419.2	4413.6	1617.8	702.5	1802.6
PRMETALS	1881.9	703192.7	218471.9	136099.9	67587.7
FAMETALS	2034.8	48137.4	40593.5	23677.4	23425.3
MEMACHIN	3579.5	89425.5	19178.7	112067.0	9394.4
ELMACHIN	652.7	21890.5	2107.3	26654.4	29779.7
INSTRUME	532.3	3983.1	1453.1	2134.9	3322.5
TRANSPOT	11541.2	39484.7	9923.1	7548.3	5930.2
COMUNICA	796.1	3107.0	1310.8	2355.1	980.6
UTILITES	18424.4	107405.1	9299.3	9029.6	4236.9
WHOLSALE	3696.6	54240.0	13260.2	15662.1	8955.0
RETAILTR	56.6	490.7	201.4	465.2	52.9
FINANINS	3710.5	10660.7	6685.9	9368.0	3896.1
SERVICES	12784.2	63512.8	25457.3	29974.1	25225.6
FEDLGOVT	416.3	1312.6	465.6	768.5	409.7
S&LOGOVT	16.1	2236.9	37.4	31.7	2.2
VALADDED	217514.5	1267225.7	318114.9	408836.2	186204.5
PIMPORTS	22620.5	231820.4	38927.8	44348.2	35100.3
TOTINPUT	364847.0	3010655.0	748612.0	856696.0	444308.0

	INSTRUME	TRANSPOT	COMUNICA	UTILITES	WHOLSALE
AGRICULT	33.1	9.2	276.9	1254.5	258.7
UNDECOAL	44.6	3.5	0.0	50799.0	0.0
SURFCOAL	117.3	3.1	0.0	33910.3	0.0
OTMINING	68.9	13.7	0.0	42752.6	0.0
CONSTRUC	509.7	1181.3	3737.0	25973.0	971.5
FOODKIND	126.3	78.4	11.8	34.5	203.0
TEXTILES	543.2	70.2	24.2	67.2	32.2
LUMBERWD	5858.7	549.5	105.0	462.1	3221.8
PRINTING	237.0	626.3	559.2	1490.7	1196.2
CHEMICAL	11042.6	20244.4	172.1	47823.0	6788.4
STONECGL	2878.5	39.0	3.5	101.7	185.4
PRMETALS	32895.3	341.3	90.6	362.1	18.5
FAMETALS	25189.1	511.4	0.5	119.8	95.8
MEMACHIN	9420.2	893.0	10.2	2749.5	570.3
ELMACHIN	6335.9	611.4	92.1	594.9	109.0
INSTRUME	36645.3	2011.1	53.2	339.7	250.3
TRANSPOT	2846.2	33022.9	421.6	3681.5	6191.6
COMUNICA	496.1	3073.0	1359.6	1897.6	4498.4
UTILITES	2065.2	1036.2	1356.8	155344.6	3745.8
WHOLSALE	8571.5	5330.1	176.5	4816.1	4419.4
RETAILTR	113.3	2227.3	41.7	282.8	949.0
FINANINS	1519.1	6266.2	2592.9	7820.8	6681.6
SERVICES	12378.3	26708.8	11562.1	21463.8	43742.3
FEDLGOVT	282.2	388.6	414.7	1654.5	915.9
S&LOGOVT	39.3	592.7	86.0	140.5	365.5
VALADDED	101907.9	184146.4	89732.2	425722.3	340627.1
PIMPORTS	33429.2	27301.1	7457.8	30176.1	15449.2
TOTINPUT	295834.0	317455.0	120287.0	862173.0	441406.0

TABLE C-I (continued).—1978 Regional Flow Table for the 15 Coal Producing Counties in Ohio.

	RETAILTR	FINANINS	SERVICES	FEDLGOVT	S&LOGOVT
AGRICULT	112.7	303.2	22635.9	2.8	270.5
UNDECOAL	0.0	1.4	268.3	1.0	84.1
SURFCOAL	0.0	2.6	269.1	2.3	200.0
OTMINING	0.0	0.0	0.0	0.0	85.5
CONSTRUC	2594.9	10417.1	31025.1	152.6	104507.9
FOODKIND	40.0	240.6	152225.1	7.2	53.9
TEXTILES	26.9	1.6	5972.9	3.7	347.7
LUMBERWD	3789.6	3478.5	11721.3	112.2	380.4
PRINTING	797.0	19860.4	18663.8	306.6	1310.3
CHEMICAL	6602.0	5693.8	70452.7	967.1	22328.5
STONECGL	140.1	42.5	4476.9	25.2	87.1
PRMETALS	7.4	16.8	401.7	31.1	0.0
FAMETALS	192.3	18.4	6557.4	126.1	611.8
MEMACHIN	173.3	255.9	8059.6	39.3	1381.0
ELMACHIN	107.5	185.3	2235.7	35.0	155.0
INSTRUME	166.5	796.4	29005.6	84.1	153.0
TRANSPOT	1332.7	3017.3	20021.3	1528.4	2631.4
COMUNICA	2903.6	12068.5	14253.4	106.5	1909.7
UTILITES	14597.9	15206.9	58246.6	1126.0	24787.3
WHOLSALE	2034.4	2370.9	45924.1	136.8	1517.3
RETAILTR	644.2	1090.0	2512.7	3.8	981.0
FINANINS	19277.7	96912.1	80963.4	1210.2	6374.9
SERVICES	37290.2	125425.0	225306.9	3281.2	21390.6
FEDLGOVT	2210.9	16034.6	9895.7	156.1	345.7
S&LOGOVT	277.6	408.2	1626.2	31.1	24.8
VALADDED	409351.6	389180.7	1659130.2	38175.3	166128.2
PIMPORTS	22124.4	98652.5	285345.9	4653.6	41559.2
TOTINPUT	526772.0	802053.0	2770349.0	52288.0	399608.0

	CONSUMPT	FEXPORTS	TOTOUTPT
AGRICULT	63193.0	0.0	347701.0
UNDECOAL	8960.0	66094.8	206522.0
SURFCOAL	11945.0	362700.6	490862.0
OTMINING	3692.0	37049.3	290716.0
CONSTRUC	457794.0	0.0	594558.0
FOODKIND	590250.0	0.0	823864.0
TEXTILES	163121.0	0.0	94061.0
LUMBERWD	95099.0	4142.3	370041.0
PRINTING	66524.0	0.0	130506.0
CHEMICAL	366497.0	0.0	1061122.0
STONECGL	18944.0	264090.8	364847.0
PRMETALS	56284.0	1734984.3	3010655.0
FAMETALS	71545.0	385284.4	748612.0
MEMACHIN	431802.0	102713.2	856696.0
ELMACHIN	207630.0	129337.8	444308.0
INSTRUME	264273.0	0.0	295834.0
TRANSPOT	153370.0	0.0	317455.0
COMUNICA	83840.0	0.0	120287.0
UTILITES	219672.0	162638.5	862173.0
WHOLSALE	331973.0	0.0	441406.0
RETAILTR	669042.0	0.0	526772.0
FINANINS	883198.0	0.0	802053.0
SERVICES	1280901.0	652690.3	2770349.0
FEDLGOVT	19334.0	0.0	52288.0
S&LOGOVT	297643.0	95421.4	399608.0

TABLE C-II.—1978 Regional Technical Coefficients Matrix (25 x 25) for the 15 Coal Producing Counties in Ohio.

	AGRICULT	UNDECOAL	SURFCOAL	OTMINING	CONSTRUC
AGRICULT	0.164429	0.0	0.0	0.000009	0.001276
UNDECOAL	0.000018	0.007175	0.057991	0.000078	0.0
SURFCOAL	0.000010	0.012141	0.105103	0.000288	0.0
OTMINING	0.000789	0.000535	0.000106	0.031739	0.006800
CONSTRUC	0.005093	0.013758	0.000026	0.018317	0.000233
FOODKIND	0.077904	0.000064	0.0	0.000046	0.000080
TESTILES	0.000273	0.000224	0.000126	0.000093	0.001786
LUMBERWD	0.004168	0.004406	0.000106	0.001197	0.055037
PRINTING	0.000471	0.000313	0.000003	0.000180	0.000232
CHEMICAL	0.046563	0.074128	0.0	0.025941	0.045242
STONECGL	0.000337	0.009439	0.0	0.000220	0.054915
PRMETALS	0.000125	0.028385	0.0	0.012660	0.033760
FAMETALS	0.005255	0.004490	0.009882	0.006173	0.096350
MEMACHIN	0.006439	0.053333	0.029356	0.029642	0.021044
ELMACHIN	0.000429	0.0	0.002050	0.003746	0.021233
INSTRUME	0.000932	0.001678	0.000015	0.001968	0.003383
TRANSPOT	0.012546	0.001476	0.003034	0.003653	0.011971
COMUNICA	0.001394	0.000280	0.000303	0.000837	0.001516
UTILITES	0.007892	0.041467	0.001463	0.019559	0.001340
WHOLSALE	0.017201	0.013954	0.008910	0.006140	0.023385
RETAILTR	0.001897	0.000510	0.000138	0.000519	0.023347
FINANINS	0.021199	0.001206	0.017037	0.040399	0.005303
SERVICES	0.018289	0.006486	0.023037	0.026862	0.053632
FEDLGOVT	0.000124	0.000307	0.000172	0.000287	0.000193
S&LOGOVT	0.000023	0.000209	0.000117	0.000419	0.000050
VALADDED	0.470034	0.695033	0.703026	0.718271	0.461265
PIMPORTS	0.136163	0.029015	0.037706	0.050757	0.076627
TOTINPUT	1.000000	1.000000	1.000000	1.000000	1.000000

	FOODKIND	TESTILES	LUMBERWD	PRINTING	CHEMICAL
AGRICULT	0.263798	0.004361	0.000208	0.000144	0.000453
UNDECOAL	0.000149	0.000053	0.001884	0.000013	0.001117
SURFCOAL	0.000167	0.000030	0.001023	0.000013	0.000607
OTMINING	0.000029	0.0	0.000272	0.0	0.023645
CONSTRUC	0.001486	0.000734	0.003746	0.003118	0.004122
FOODKIND	0.130550	0.000428	0.000087	0.000156	0.003978
TESTILES	0.000149	0.064869	0.001219	0.000287	0.000423
LUMBERWD	0.030753	0.008025	0.216965	0.144866	0.027668
PRINTING	0.005375	0.000665	0.000518	0.062097	0.001334
CHEMICAL	0.017724	0.040540	0.035516	0.025713	0.238816
STONECGL	0.009758	0.000013	0.004147	0.000032	0.005199
PRMETALS	0.000482	0.000255	0.041070	0.001770	0.011761
FAMETALS	0.020929	0.000894	0.033931	0.001526	0.022358
MEMACHIN	0.001688	0.001542	0.004385	0.003588	0.011087
ELMACHIN	0.000032	0.000029	0.000116	0.000041	0.000799
INSTRUME	0.000226	0.000146	0.000790	0.001051	0.002029
TRANSPOT	0.008367	0.011188	0.012594	0.016319	0.018902
COMUNICA	0.001031	0.002732	0.001525	0.005937	0.002188
UTILITES	0.007618	0.007312	0.017365	0.007001	0.019924
WHOLSALE	0.023398	0.028746	0.025504	0.014366	0.018081
RETAILTR	0.000325	0.000299	0.000281	0.000620	0.000289
FINANINS	0.003832	0.010242	0.009114	0.011196	0.008046
SERVICES	0.027971	0.037923	0.031054	0.063601	0.043211
FEDLGOVT	0.000699	0.001991	0.000706	0.003646	0.000854
S&LOGOVT	0.000109	0.000044	0.000268	0.000083	0.000154
VALADDED	0.256383	0.274451	0.391502	0.584777	0.402358
PIMPORTS	0.186973	0.302485	0.143239	0.048038	0.130398
TOTINPUT	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE C-II (continued).—1978 Regional Technical Coefficients Matrix (25 x 25) for the 15 Coal Producing Counties in Ohio.

	STONECGL	PRMETALS	FAMETALS	MEMACHIN	ELMACHIN
AGRICULT	0.000155	0.000117	0.000324	0.000074	0.000063
UNDECOAL	0.002210	0.015610	0.000409	0.000172	0.000048
SURFCOAL	0.001483	0.008477	0.000222	0.000094	0.000114
OTMINING	0.036396	0.051192	0.000801	0.000023	0.000253
CONSTRUC	0.005488	0.008591	0.002546	0.002364	0.003248
FOODKIND	0.000041	0.000037	0.000083	0.000209	0.000107
TESTILES	0.000074	0.000166	0.000291	0.000182	0.000381
LUMBERWD	0.025963	0.005052	0.015913	0.006150	0.020535
PRINTING	0.001151	0.000793	0.002471	0.001006	0.001144
CHEMICAL	0.061512	0.028740	0.032685	0.020549	0.059369
STONECGL	0.042262	0.001466	0.002161	0.000820	0.004057
PRMETALS	0.005158	0.233568	0.291836	0.158866	0.152119
FAMETALS	0.005577	0.015989	0.054225	0.027638	0.052723
MEMACHIN	0.009811	0.029703	0.025619	0.130813	0.021144
ELMACHIN	0.001789	0.007271	0.002815	0.031113	0.067025
INSTRUME	0.001459	0.001323	0.001941	0.002492	0.007478
TRANSPOT	0.031633	0.013115	0.013254	0.008811	0.013347
COMUNICA	0.002182	0.001032	0.001751	0.002749	0.002207
UTILITES	0.050499	0.035675	0.012422	0.010540	0.009536
WHOLSALE	0.010132	0.018016	0.017713	0.018282	0.020135
RETAILTR	0.000135	0.000163	0.000269	0.000543	0.000119
FINANINS	0.010170	0.003541	0.008931	0.010935	0.008769
SERVICES	0.035040	0.021096	0.034006	0.034988	0.036775
FEDLGOVT	0.001141	0.000436	0.000622	0.000897	0.000922
S&LOGOVT	0.000044	0.000743	0.000050	0.000037	0.000005
VALADDED	0.596180	0.420914	0.424940	0.477224	0.419089
PIMPORTS	0.062292	0.077175	0.051700	0.052428	0.079249
TOTINPUT	1.000000	1.000000	1.000000	1.000000	1.000000

	INSTRUME	TRANSPOT	COMUNICA	UTILITES	WHOLSALE
AGRICULT	0.000112	0.000029	0.002302	0.001455	0.000586
UNDECOAL	0.000131	0.000011	0.0	0.058920	0.0
SURFCOAL	0.000396	0.000010	0.0	0.039331	0.0
OTMINING	0.000233	0.000043	0.0	0.049587	0.0
CONSTRUC	0.001723	0.003721	0.031067	0.030125	0.002201
FOODKIND	0.000427	0.000247	0.000098	0.000040	0.000460
TESTILES	0.001836	0.000221	0.000201	0.000078	0.000073
LUMBERWD	0.019804	0.001731	0.000873	0.000536	0.007299
PRINTING	0.000801	0.001973	0.004649	0.001729	0.002710
CHEMICAL	0.037327	0.063771	0.001431	0.055468	0.015379
STONECGL	0.009730	0.000123	0.000029	0.000118	0.000420
PRMETALS	0.111195	0.001075	0.000753	0.000420	0.000042
FAMETALS	0.085146	0.001611	0.000004	0.000139	0.000217
MEMACHIN	0.031843	0.002813	0.000085	0.003189	0.001292
ELMACHIN	0.021417	0.001926	0.000766	0.000690	0.000247
INSTRUME	0.123871	0.006335	0.000442	0.000394	0.000567
TRANSPOT	0.009621	0.104024	0.003505	0.004270	0.014027
COMUNICA	0.001677	0.009680	0.011303	0.002201	0.010191
UTILITES	0.006981	0.003264	0.011280	0.180178	0.008486
WHOLSALE	0.028974	0.016790	0.001467	0.005386	0.010012
RETAILTR	0.000383	0.007016	0.000317	0.000328	0.002150
FINANINS	0.005135	0.019739	0.021356	0.009071	0.015137
SERVICES	0.041842	0.084134	0.096121	0.024895	0.099098
FEDLGOVT	0.000954	0.001224	0.003448	0.001919	0.002075
S&LOGOVT	0.000133	0.001867	0.000715	0.000163	0.000828
VALADDED	0.344477	0.580071	0.745984	0.493778	0.771687
PIMPORTS	0.113814	0.086352	0.061574	0.035393	0.034819
TOTINPUT	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE C-II (continued).—1978 Regional Technical Coefficients Matrix (25 x 25) for the 15 Coal Producing Counties in Ohio.

	RETAILTR	FINANINS	SERVICES	FEDLGOVT	S&LOGOVT
AGRICULT	0.000214	0.000378	0.008178	0.000054	0.000677
UNDECOAL	0.0	0.000002	0.000097	0.000019	0.000211
SURFCOAL	0.0	0.000003	0.000097	0.000044	0.000500
OTMINING	0.0	0.0	0.0	0.0	0.000214
CONSTRUC	0.004926	0.012988	0.011199	0.002919	0.261526
FOODKIND	0.000076	0.000300	0.054948	0.000137	0.000135
TESTILES	0.000051	0.000002	0.002156	0.000071	0.000870
LUMBERWD	0.007194	0.004337	0.004231	0.002145	0.000952
PRINTING	0.001513	0.024762	0.006737	0.005863	0.003279
CHEMICAL	0.012533	0.007099	0.025431	0.018496	0.055876
STONECGL	0.000266	0.000053	0.001616	0.000481	0.000218
PRMETALS	0.000014	0.000021	0.000145	0.000595	0.0
FAMETALS	0.000365	0.000023	0.002367	0.002411	0.001531
MEMACHIN	0.000329	0.000319	0.003198	0.000751	0.003456
ELMACHIN	0.000204	0.000231	0.000807	0.000669	0.000308
INSTRUME	0.000316	0.000993	0.010470	0.001609	0.000383
TRANSPOT	0.002530	0.003762	0.007227	0.029230	0.006585
COMUNICA	0.005512	0.013047	0.005145	0.002036	0.004779
UTILITES	0.027712	0.018960	0.021025	0.021535	0.062029
WHOLSALE	0.003862	0.002956	0.016577	0.002616	0.003797
RETAILTR	0.001223	0.001359	0.000907	0.000072	0.002455
FINANINS	0.036596	0.120830	0.029225	0.023145	0.015953
SERVICES	0.070790	0.156380	0.081328	0.062753	0.053529
FEDLGOVT	0.004197	0.019992	0.003572	0.002985	0.000865
S&LOGOVT	0.000527	0.000509	0.000587	0.000595	0.000062
VALADDED	0.777095	0.485231	0.598089	0.730097	0.415728
PIMPORTS	0.041954	0.123461	0.103841	0.080671	0.104000
TOTINPUT	1.000000	1.000000	1.000000	1.000000	1.000000

TABLE C-III.—1978 Regional Interdependence Coefficients Matrix (25 x 25) for the 15 Coal Producing Counties in Ohio.

	AGRICULT	UNDECOAL	SURFCOAL	OTMINING	CONSTRUC
AGRICULT	1.233395	0.001275	0.001310	0.001825	0.004828
UNDECOAL	0.001593	1.012986	0.066251	0.002708	0.003562
SURFCOAL	0.001118	0.017116	1.118965	0.002141	0.002323
OTMINING	0.004969	0.010298	0.002026	1.037612	0.018483
CONSTRUC	0.009093	0.017913	0.002590	0.622229	1.005484
FOODKIND	0.113973	0.002434	0.002709	0.003645	0.006806
TESTILES	0.000594	0.000459	0.000298	0.000329	0.002389
LUMBERWD	0.016841	0.013593	0.002960	0.007253	0.082075
PRINTING	0.002946	0.001300	0.001196	0.002283	0.002405
CHEMICAL	0.088094	0.113948	0.013158	0.947004	0.092478
STONECGL	0.002880	0.012011	0.001118	0.002142	0.059432
PRMETALS	0.011799	0.061666	0.018677	0.034290	0.107763
FAMETALS	0.014116	0.013810	0.014812	0.013107	0.113450
MEMACHIN	0.012467	0.068295	0.043650	0.039066	0.036057
ELMACHIN	0.001615	0.003575	0.004274	0.006517	0.023870
INSTRUME	0.002521	0.003108	0.000980	0.003536	0.006403
TRANSPOT	0.022439	0.007872	0.006092	0.008054	0.024613
COMUNICA	0.003564	0.001623	0.001407	0.002573	0.004082
UTILITES	0.019400	0.060442	0.009390	0.031535	0.021452
WHOLSALE	0.028753	0.021332	0.013944	0.011386	0.036302
RETAILTR	0.002961	0.001195	0.000437	0.001325	0.024029
FINANINS	0.035013	0.007152	0.024795	0.051866	0.017469
SERVICES	0.047639	0.026543	0.039454	0.050071	0.091422
FEDLGOVT	0.001391	0.000973	0.000998	0.001760	0.001547
S&LOGOVT	0.000192	0.000354	0.000227	0.000564	0.000346

TABLE C-III (continued).—1978 Regional Interdependence Coefficients Matrix (25 x 25) for the 15 Coal Producing Counties in Ohio.

	FOODKIND	TESTILES	LUMBERWD	PRINTING	CHEMICAL
AGRICULT	0.375931	0.007929	0.002899	0.003539	0.005472
UNDECOAL	0.002202	0.001168	0.006698	0.002130	0.005026
SURFCOAL	0.001612	0.000816	0.004307	0.001444	0.003341
OTMINING	0.004839	0.002677	0.010534	0.003924	0.037570
CONSTRUC	0.006723	0.002948	0.009315	0.007242	0.010033
FOODKIND	1.188223	0.005255	0.005282	0.006990	0.011903
TESTILES	0.000598	1.069578	0.001963	0.000889	0.000943
LUMBERWD	0.055436	0.015118	1.285594	0.202249	0.051844
PRINTING	0.008502	0.001991	0.002607	1.068062	0.003612
CHEMICAL	0.066317	0.065141	0.111363	0.061868	1.335267
STONECGL	0.013524	0.000827	0.007289	0.002049	0.008631
PRMETALS	0.020785	0.005114	0.095529	0.022106	0.045004
FAMETALS	0.033872	0.004130	0.052694	0.012698	0.037426
MEMACHIN	0.009201	0.003893	0.014702	0.008613	0.022933
ELMACHIN	0.001236	0.000503	0.002156	0.001061	0.003085
INSTRUME	0.002111	0.001282	0.002904	0.003167	0.004840
TRANSPOT	0.021662	0.016689	0.024973	0.026144	0.032851
COMUNICA	0.003551	0.004315	0.003982	0.008397	0.004834
UTILITES	0.022957	0.014606	0.039251	0.020346	0.041606
WHOLSALE	0.040657	0.034743	0.040972	0.025553	0.031221
RETAILTR	0.001657	0.000712	0.001040	0.001300	0.001126
FINANINS	0.020315	0.017021	0.020506	0.021889	0.020537
SERVICES	0.063773	0.050300	0.068478	0.097142	0.082973
FEDLGOVT	0.001880	0.002916	0.001999	0.005090	0.002217
S&LOGOVT	0.000316	0.000178	0.000586	0.000325	0.000435

	STONECGL	PRMETALS	FAMETALS	MEMACHIN	ELMACHIN
AGRICULT	0.002588	0.002241	0.003031	0.002705	0.003582
UNDECOAL	0.007588	0.026100	0.010213	0.006852	0.006623
SURFCOAL	0.005438	0.016094	0.006431	0.004361	0.004330
OTMINING	0.046959	0.076167	0.027751	0.017718	0.018761
CONSTRUC	0.011220	0.017304	0.010494	0.008642	0.009961
FOODKIND	0.004797	0.004049	0.005277	0.005341	0.007209
TESTILES	0.000400	0.000514	0.000715	0.000565	0.000905
LUMBERWD	0.041570	0.015704	0.031071	0.017583	0.039039
PRINTING	0.002902	0.002543	0.004744	0.003131	0.003534
CHEMICAL	0.105003	0.072119	0.078779	0.058343	0.113258
STONECGL	1.045919	0.004140	0.004669	0.002905	0.006959
PRMETALS	0.022653	1.335728	0.425267	0.270540	0.256438
FAMETALS	0.013487	0.030387	1.071673	0.044912	0.072425
MEMACHIN	0.017984	0.053831	0.050387	1.165088	0.041354
ELMACHIN	0.003667	0.013354	0.008950	0.041709	1.076318
INSTRUME	0.003475	0.003730	0.004697	0.005491	0.011691
TRANSPOT	0.042362	0.024803	0.026965	0.020141	0.026691
COMUNICA	0.004225	0.003197	0.004218	0.005256	0.004867
UTILITES	0.073607	0.067449	0.042647	0.033787	0.034004
WHOLSALE	0.018051	0.031337	0.033301	0.032295	0.035281
RETAILTR	0.000971	0.001089	0.001067	0.001263	0.000914
FINANINS	0.020792	0.015212	0.020258	0.022295	0.020820
SERVICES	0.063046	0.053789	0.070670	0.071038	0.097477
FEDLGOVT	0.002285	0.001534	0.001908	0.002213	0.002323
S&LOGOVT	0.000274	0.001179	0.000550	0.000401	0.000400

TABLE C-III (continued).—1978 Regional Interdependence Coefficients Matrix (25 x 25) for the 15 Coal Producing Counties in Ohio.

	INSTRUME	TRANSPOT	COMUNICA	UTILITES	WHOLSALE
AGRICULT	0.003401	0.004216	0.006675	0.004251	0.004768
UNDECOAL	0.006188	0.001177	0.001361	0.076807	0.001158
SURFCOAL	0.004332	0.000823	0.000973	0.055487	0.000827
OTMINING	0.017008	0.003979	0.002003	0.067186	0.001893
CONSTRUC	0.008111	0.008218	0.034359	0.041409	0.005443
FOODKIND	0.006751	0.008898	0.008256	0.004433	0.008761
TESTILES	0.002673	0.000661	0.000590	0.000427	0.000421
LUMBERWD	0.040239	0.009824	0.006930	0.010363	0.013292
PRINTING	0.003141	0.004549	0.006885	0.003655	0.004701
CHEMICAL	0.088425	0.104080	0.013051	0.108952	0.030517
STONECGL	0.013847	0.001707	0.002467	0.004185	0.001339
PRMETALS	0.232518	0.010748	0.006438	0.017187	0.003992
FAMETALS	0.115406	0.007644	0.005161	0.010225	0.003024
MEMACHIN	0.057441	0.007130	0.002500	0.017267	0.003264
ELMACHIN	0.030877	0.003335	0.001989	0.003227	0.000814
INSTRUME	1.144034	0.010024	0.002271	0.002195	0.002436
TRANSPOT	0.023489	1.121108	0.006875	0.011314	0.018573
COMUNICA	0.004474	0.012831	1.012894	0.004190	0.011857
UTILITES	0.030812	0.013271	0.019418	1.232182	0.016308
WHOLSALE	0.047101	0.024899	0.005901	0.014613	1.014377
RETAILTR	0.001175	0.008352	0.001406	0.001710	0.002629
FINANINS	0.017028	0.032387	0.030385	0.021580	0.023466
SERVICES	0.085336	0.121626	0.118014	0.054673	0.120821
FEDLGOVT	0.002354	0.002775	0.004672	0.003285	0.003195
S&LOCOVT	0.000520	0.002252	0.000847	0.000371	0.000987

	RETAILTR	FINANINS	SERVICES	FEDLGOVT	S&LOCOVT
AGRICULT	0.003314	0.007308	0.034301	0.002855	0.004799
UNDECOAL	0.002369	0.002396	0.002522	0.002134	0.006486
SURFCOAL	0.001848	0.001725	0.001839	0.001564	0.004985
OTMINING	0.002981	0.003048	0.003855	0.002884	0.011791
CONSTRUC	0.008547	0.019795	0.015440	0.006073	0.267621
FOODKIND	0.006352	0.014426	0.073579	0.005868	0.007347
TESTILES	0.000330	0.000598	0.002706	0.000334	0.001809
LUMBERWD	0.012835	0.017105	0.015249	0.007312	0.028354
PRINTING	0.003793	0.032352	0.009892	0.008002	0.005733
CHEMICAL	0.026559	0.027723	0.050737	0.035630	0.110575
STONECGL	0.001266	0.002047	0.004106	0.001377	0.016846
PRMETALS	0.003784	0.006100	0.010521	0.005614	0.034545
FAMETALS	0.003162	0.005053	0.009829	0.005327	0.035097
MEMACHIN	0.002221	0.003407	0.007461	0.002934	0.016562
ELMACHIN	0.000735	0.001323	0.002162	0.001325	0.007913
INSTRUME	0.001746	0.004213	0.013824	0.003330	0.003470
TRANSPOT	0.005545	0.009993	0.013486	0.035333	0.017675
COMUNICA	0.007161	0.019291	0.007334	0.003670	0.007358
UTILITES	0.039299	0.035413	0.034130	0.031434	0.087509
WHOLSALE	0.007540	0.010278	0.024498	0.006678	0.018079
RETAILTR	1.001673	0.002390	0.001722	0.000642	0.009131
FINANINS	0.046622	1.147943	0.041036	0.031530	0.028441
SERVICES	0.092026	0.209148	1.111136	0.083194	0.097828
FEDLGOVT	0.005669	0.024136	0.005164	1.004145	0.002365
S&LOCOVT	0.000652	0.000791	0.000769	0.000738	1.000283

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